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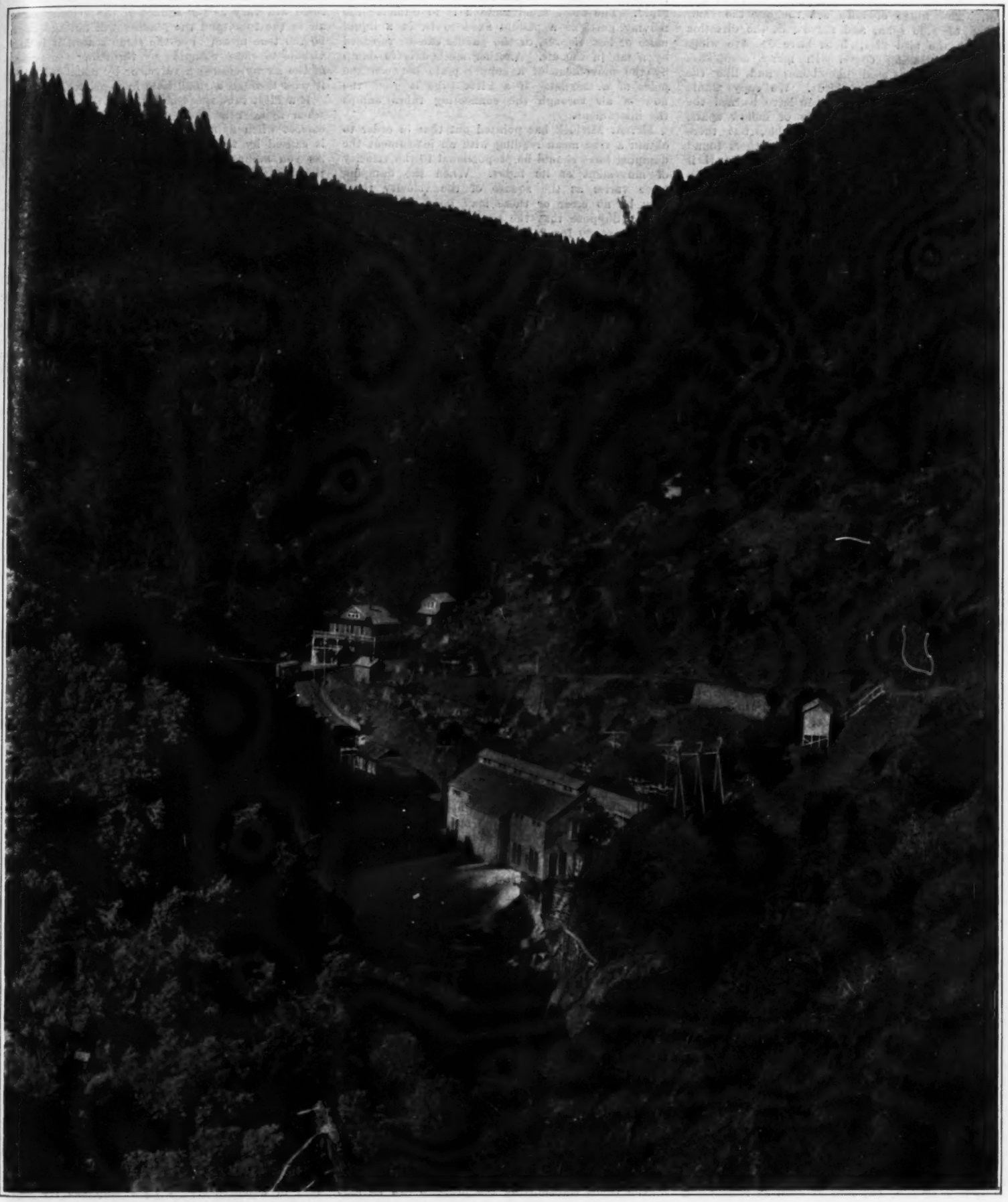


The plant at Sabla, Cal.

HYDRO-ELECTRIC POWER DEVELOPMENT IN CALIFORNIA.—[See page 72.]

Design and Use of Scientific Instruments in Aeronautics*

Correct Design Eliminates Unnecessary Strains

By Horace Darwin, F. R. S.

THE resemblance of the manufactured aeroplane and the living bird may be simply the result of copying the bird, or it may be that similar designs have been arrived at independently by birds and men. The wings of both are roughly the same shape: of wide span, and narrow in the direction in which the bird flies; both have concave wings with thick leading edges. In many aeroplanes hollow spars are used like bones and like the quills of the feathers of birds. We copy plants also in this respect, for they too have learned the economy of material in the use of hollow spars.

These resemblances are remarkable, but there are great differences. The Wright brothers found no biplane bird to copy and did not flap their wings. No flying animal uses a continuously rotating propeller to drive him forward on soaring wings, and it is perhaps scarcely too much to say that if birds only knew how, they would now copy the Wright brothers. Muscular action and the circulation of the blood, however, put supreme difficulties in the way of the development of the continuous rotation of a part of an animal.

INSTRUMENTS USED IN AEROPLANES.

It is important to realize beforehand the difficulties of using instruments on aeroplanes during flight and the errors that may be introduced in the readings. The aeroplane shakes, it does not remain level and is subject to acceleration in all directions. The instrument should be so designed as not to be affected by any of these disturbances. A vertical acceleration has the same effect as a change in the amount of the downward pull due to gravity; the tilting of the aeroplane changes the direction of the downward pull with regard to the instrument. A lateral or longitudinal acceleration has the effect of altering both the direction and the amount of gravity. But vibration is a greater difficulty still. The hand of an instrument may move so much and so rapidly that it is difficult to estimate the mean reading on the scale and sometimes it is quite impossible to do so. And this may happen when the quantity which is indicated by the position of the hand only varies slowly and by small amounts. The moving part of an instrument should be well balanced. This reduces the vibration from the shaking of the aeroplane as well as the error caused by its tilting or want of level.

In a compass as ordinarily made, the condition of balance cannot be fulfilled. The magnet rests on a steel point, is horizontal, and its center of gravity is below the steel point. The force on the north pole acts in a downward direction toward the north, and the force on the south pole in an upward direction toward the south, and the magnet is made to rest in a horizontal position by arranging that the center of gravity of the magnet is between its south end and its center. It is below and to one side of the point about which rotation takes place. Hence, a sideways movement must start it swinging. The magnet and card in aeroplane and ship compasses are usually surrounded by a liquid, so that any vibration which may be caused by its want of balance is rapidly reduced.

Instruments on aeroplanes should be damped, using the word "damp" in the sense of "to dull" or "to abate the motion of." This damping is specially important if it should happen that the rate of vibration of the whole instrument should agree with the natural rate of vibration of the moving part. When this happens with an undamped instrument the vibration is excessive. Damping is also required in cases where the fluctuations in the quantity to be measured are rapid; it may then be difficult to read the instrument and the excursions of the hand may indicate a much greater amount of variation of the quantity than really takes place. If the mean reading is required the instrument must be damped, and the damping should be of a particular kind.

The essential features of satisfactory damping are that no force should be applied to the moving part while it is at rest, but that as soon as it moves a force should act opposing the movement. Friction at the joint does damp the instrument, but does not fulfil these conditions and is bad. The force should be small when the movement is slow and it should increase when the movement becomes more rapid. The most usual method is to immerse the moving part, or a paddle fixed to it, in a liquid more or less viscous, or the paddle can be replaced by a fan in the air. Another method is to damp by the movement of a copper plate between the poles of a magnet. If a Pitot tube is used the flow of air through the connecting tubes damps the instrument.

Mr. A. Mallock has pointed out that in order to obtain a true mean reading with an instrument the damping force should be proportional to the velocity of movement of its index. When the damping force varies as the square of the velocity there may be no error or there may be a considerable error. Suppose that the quantity to be measured remains at 80 for 2/10 second, and then suddenly increases to 140 and remains at that amount for 1/10 second, and then goes back to 80 and remains at that amount for 2/10 second, and that this rapid oscillation goes on indefinitely. Suppose also that the instrument is damped by a force which varies as the square of the velocity of the index, and that it is so much damped that the hand appears to remain at rest. The reading of the instrument will be 92 and the true mean in reality is 100, so that we have an error amounting to 8 per cent, by no means a small error. The accompanying diagram gives the supposed variations of the quantity as it would be recorded on a moving sheet of paper, and gives the true mean and the instrument reading.

In the magnetic method of damping the force varies as the velocity and the true mean is obtained. With liquid and air damping the force varies as the square of the velocity, unless the movement is extremely slow, when it varies nearly as the velocity.

SPEED OF AEROPLANES.

The speed of the aeroplane through the air is often measured by a Pitot tube and a manometer.

The principle of the Pitot tube is very simple. If the open end of a tube faces the wind, the air wants to pass down the tube; if the tube is closed at the other end the air pressure is increased in the tube, and this increase of pressure is a remarkably accurate means of measuring the velocity of the wind. This method is used in Dines's anemometer, and for measuring the velocity of the air in the wind channel at the National Physical Laboratory. In 1903 Dr. Stanton read a paper before the Institution of Civil Engineer (Proc. Inst. C.E., vol. clvi,, p. 78) proving the accuracy of this method of measuring air velocity, and improvements have recently been made which give even more satisfactory results. The delicate measurement of the air pressure necessary for the most refined work is made by the tilting water gauge designed by Prof. A. P. Chattock and Mr. J. D. Fry. This is a laboratory instrument of the highest order of precision, and is far too delicate and accurate to be used on a flying machine. It is a difference of pressure that has to be measured, the increase of pressure in the tube above the air pressure outside, and a second tube transmits this pressure (the static pressure) to the manometer. It is found by experiment that changes in the size of the opening of the Pitot tube, or the thickness of the tube, or the bevelling of its edge, make little or no difference in the pressure. With the opening of the static tube it is different and its design is important. In the design now adopted at the National Physical Laboratory the pressure obtained is almost exactly what we should expect from theoretical considerations. This is an advantageous simplification, and this form of Pitot tube should be used for all the most refined measurements. But the static tube can be so made that it will give a pressure below the true static pressure, and the Royal Aircraft Factory has made use of this by increasing the manometer readings by 20 per cent in order to give a more open scale.

The tubes transmitting the pressure can be carried a considerable distance to allow the manometer to be placed in a convenient position for reading; this is often of great importance. If it is found advisable to have a large amount of damping in the manometer it is best to have long tubes of large diameter. This gives the correct form of damping. Short tubes of small diameter will also give a large amount of damping, but in this case the damping force will vary as the square of the velocity of the air in the tube, and the reading will not necessarily be the true mean. For the same reason it is inadvisable to cause damping by throttling the passage of the air by closing a valve, or by means of letting it pass through a small hole in a plate.

If a Pitot tube speed-meter gives the correct speed when flying near the ground level, it will not be correct when flying at a great altitude. The error is caused by the change in the density of the air. As you mount the air becomes less dense because the atmospheric pressure is reduced, and more dense because the temperature falls, and an error of 7 per cent may be expected at an altitude of 5,000 feet.

The simplest form of manometer is a U-tube containing a liquid. The difference of the level of the liquid is then a measure of the difference of the air pressure in the two tubes. For use on an aeroplane this has two drawbacks; the scale is not open enough to read the speed easily and accurately, and tilting of the aeroplane causes an error. Mr. Short, of the Royal Aircraft Factory, has designed a manometer which overcomes both these objections. It is in effect a U-tube manometer; he uses two liquids of different densities, which do not mix, and thus obtains a more open scale. One tube is placed inside the other, and this overcomes the chief error due to the tilting of the aeroplane, leaving only a small secondary error amounting to 1½ per cent for a displacement of 10 degrees out of the vertical. If the aeroplane has an upward or downward acceleration or is changing its direction there is an error.

If a Pitot tube is fixed to the tips of the wings of an aeroplane and it is flying in a circle, the speed of the outer wing tip is greater than the speed of the inner wing tip. If these Pitot tubes are joined together by a tube there will be a greater pressure at one end of the tube than at the other, and at first sight we should expect that there would be a flow of air through the tube from the outer to the inner wing tip. But this is not the case, because the aeroplane is moving in a circle and there will be centrifugal force acting on the air in the tube. This will tend to make it flow outward, and will exactly balance the tendency of the air to flow inward due to the excess pressure in the Pitot tube on the outer wing tip, and there will be no flow through the tube. If there is a side-slip this statement is only approximately true. For accurate speed measurements at the Royal Aircraft Factory two Pitot tubes are used, one at each wing tip; both are connected to the manometer and the mean speed is given.

An instrument called a yaw-meter was described. It measures the direction in which the air is moving relatively to an aeroplane, and its action depends on the fact that the pressure in a Pitot tube becomes less if it does not directly face the wind. Two Pitot tubes are used, and the indication is independent of the speed of flight.

THE PRINCIPLE OF GEOMETRICAL DESIGN.

Clerk Maxwell writes:

"Each solid piece of an instrument is intended to be either fixed or movable, and to have a certain definite shape. It is acted on by its own weight and other forces, but it ought not to be subjected to unnecessary stresses, for these not only diminish its strength, but (what for scientific purposes may be much more injurious) they alter its figure and may, by their unexpected changes during the course of an experiment, produce disturbance or confusion in the observations we have to make.

"We have, therefore, to consider the methods of relieving the pieces of an instrument from unnecessary strain, of securing for the fixed parts a determinate position, and of insuring that the movable parts shall move freely, yet without shake.

"This we may do by attending to the well-known fact in kinematics: '*A rigid body has six degrees of freedom.*'"

Designs in which this principle is carried out may be called geometrical designs. A three-legged table is a geometrical design, and a four-legged table

* From the first Wilbur Wright memorial lecture delivered before the Aeronautical Society of Great Britain on May 21st, 1913, adapted from *Nature*.

is not. A four-legged table either rocks on two legs, or bends so that all legs touch the floor, and the amount of bending and the pressure of each foot on the floor depends on the stiffness of the table and the evenness of the floor. Every time an ordinary chair is placed in a new position, it takes a new shape. A surface plate is a familiar example of the importance of three supports, and nearly all scientific instruments rest on three feet.

GOOD DESIGN AND BAD WORKMANSHIP.

A most important consideration in a good design is that the instrument shall still work well when the rubbing surfaces get worn or parts get bent, or if the workmanship is not good. With perfect workmanship and a bad design, you may get jamming in the moving pieces and bending of parts which should not bend, and the results obtained will be liable to error and the working unsatisfactory. This consideration brings out most forcibly the advantage of geometrical designs, but also it is a valuable test to all designs. It is a long way from being the only test, but it is always well worth while to consider separately the effects of imperfect workmanship, or the bending of each part and wearing of the rubbing surfaces. Take the case of wear in a wheelbarrow. The axle of the wheel usually consists of two round iron pins running in holes in wooden rails forming the frame of the wheelbarrow. Both the wood and the pins wear; the pin gets smaller but keeps circular, and wears its way into the wood and always fits it properly on the side where pressure is taken. The wheel will work perfectly until either the holes break out of the wood or the pin wears down very small and itself gives way. But sometimes the axle is made differently; an iron rod is fixed to the two wooden rails and passes through a hole bored along the center of the wheel. With use the iron rod wears on the under side and does not remain circular, the hole in the wheel gets larger; the result is increased friction and a loose and shaky bearing.

The following test was applied to the Rocking Microtome, which has been designed so far as possible on the geometrical method. The iron castings of which it is chiefly made were taken as they left the foundry, were put together with as little work as possible, and it at once cut good sections. This was a severe ordeal, but sections as thin as 0.003 millimeter were cut, proving that the instrument still worked with considerable precision.

This test for good design is not the only test, and it may fail. Ball bearings are much used, and when once used for any purpose they continue to be used more and more; this is the best test of a really good mechanical device. All must admire their design, but first-rate workmanship is essential; in this must be included the composition of the steel, the skill in hardening, as well as the accuracy of the figure of the working parts. A ball bearing, however, would be a better thing even than it is at present if it did not require such fine workmanship. It also requires careful mounting, and it is interesting to notice that the recent improvements in ball-bearing design are in the direction of allowing it to work satisfactorily on shafting which may be considerably bent.

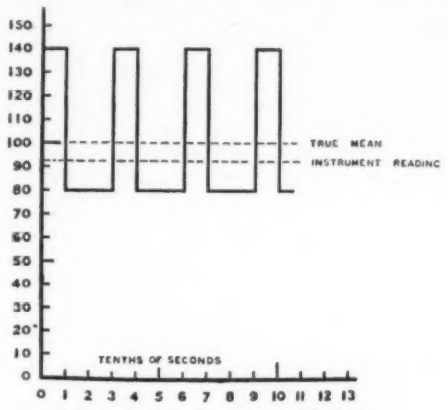


Diagram of instrument oscillations.

THE ADVANTAGE OF REVERSING THE PARTS OF A MACHINE.

An improvement in the design of a machine can often be made by reversing the relative position of two parts of it, or the part that moved can be fixed and the part that was fixed can be made to move. This reversal makes it possible to compare two or more methods, and it is then easy to see which is best. It is advantageous that "the survival of the fittest" should take place early in the life of the machine, and by this means, in fact, it takes place before the design is completed.

In the before-mentioned wheelbarrow it is easy to see which is the best design, and if the designer had deliberately considered whether the iron pins should turn in the wooden rails or whether the iron bar should be fixed, the bad design would never have been made. It is surprising how often this reversal is possible and advantageous, and how difficult it is to realize that it is possible. We are so familiar with a clock in which the frame remains at rest and the hands move that it requires a considerable mental wrench to realize that it is possible and in some cases better that the clock itself should revolve and the hour hand remain at rest. But in recording apparatus it is usual to fix the clockwork in the rotating drum carrying the paper, and to prevent rotation of the hour-hand spindle.

Radium and the Evolution of the Earth's Crust

What the Advent of Radium Means to the Geologist

By Arthur Holmes

It is now well known that if the proportion of radium in the interior of the earth is the same as that in the surface rocks, the earth ought to be growing hotter, and the temperature gradient of the crust ought to be much higher than we find it. A simple calculation shows that a distribution of radium averaging 2×10^{-14} grammes in each gramme of rock throughout the earth would suffice to preserve thermal equilibrium. The amounts of radium actually found in the surface rocks are approximately as follows:

Acid	3×10^{-12}	grammes	per gramme
Intermediate	2	"	"
Basic	1	"	"
Ultrabasic	0.5	"	"

In addition to the elements of the uranium family, those of the thorium family must also be considered, for they afford an equally important supply of heat.

Prof. Strutt was the first to indicate the way in which the obvious dilemma might be escaped. In order that the earth should be nearly in thermal equilibrium (i. e., not growing hotter, but cooling at the very slow rate allowed by the radio-active elements as they decrease in quantity in accordance with their progresssive disintegration) it is necessary to assume that the earth's store of radium is concentrated near the surface. As the following arguments indicate, this conception is less arbitrary than would appear at first sight. The radio-active elements are found most abundantly in the acid rocks, their more basic associates being less embarrassingly rich. The more acid rocks are characteristic of only the outermost zones of the crust, and there are many reasons for believing that with depth the more basic rocks largely predominate. Seismic and other terrestrial phenomena have now provided us with data from which the condition of the earth's interior may be deduced with some confidence. First, there is the crusta zone, rapidly becoming less silicic with depth, having a mean density of 2.8 and an approximate thickness of thirty miles. Within a fairly sharp surface of discontinuity comes what may be called the stony zone. The density is 3.4 and judging from the close analogy presented by meteorites, the material would be of ultrabasic composition. This zone dies out at a depth variously estimated at from 600 to 900 miles. The internal core of the earth is probably largely composed of iron, its density being about 8.

In a number of meteorites, the radium content has been determined by Prof. Strutt and the present writer, and if it may be assumed that they afford a clue to the problem, the heavy metallic core should be completely destitute of radium, and the stony zone should contain only a small proportion, very much less than that of the ultrabasic rocks of the crust.

On the planetesimal hypothesis, the two internal zones find a ready explanation. It is supposed that the earth began as a nebulous knot, and that it has grown up to its present mass by the capture of associated planetesimals. It is very unlikely that as a whole it was ever in a molten condition. Internal heat probably arose largely from the condensation of the mass during the period of its growth. The temperature would slowly rise until the fusion point of certain of the constituents was reached, and the liquid tongues and pockets thus formed would tend to move away from the center, the lighter and less viscous stony material being squeezed outward relatively to a network of the heavier and more rigid metallic materials. Once vulcanism had been initiated in this way, the process would continue until a highly metallic nucleus had collected. Surrounding it there would gradually form a thick zone of silicate rocks, the differentiation from the original heterogeneous mixture of stony and metallic constituents being due to the selective fusion of the former. There seems to be little doubt that the radio-active elements would be concentrated in the stony zone. With the establishment of ocean and atmosphere, a new factor in surface differentiation arose, and sedimentary rocks were deposited for the first time. In some way which, as yet, we understand but vaguely, both igneous and denudational differentiation then combined in developing the earth's crust. We now find in the latter all those rocks which hold a maximum content both of silica and of the raido-active elements. The relative concentration of these constituents having taken place at the expense of the zone below, the conjectural paucity of the latter in radium finds a suggestive explanation.

Before the advent of radium, geologists had not recognized the difficulties presented by the peculiar chemical constitution of the earth's crust. Radium did not create this difficulty, but has merely directed attention toward it. Any explanation of the high percentage of silica in the surface rocks will explain equally well their richness in radium.

It can scarcely be said now that radium has given us "a blank check on the bank of time." Not only did the discovery of radium destroy the validity of the older thermal arguments, but also it led directly to the elaboration of a new and more refined method. Every radio-active mineral may be regarded as a self-contained hourglass, the radio-active end-products, helium and lead, slowly accumulating at the expense of their ultimate parent, uranium. In the few cases which up to the present have been investigated, periods of enormous duration have been revealed, and the geologist who ten years ago was embarrassed by the shortness of the time allowed to him for the evolution of the earth's crust is now still more embarrassed by the superabundance with which he is confronted. The time scale up to date, as determined by the lead ratio, is as follows:

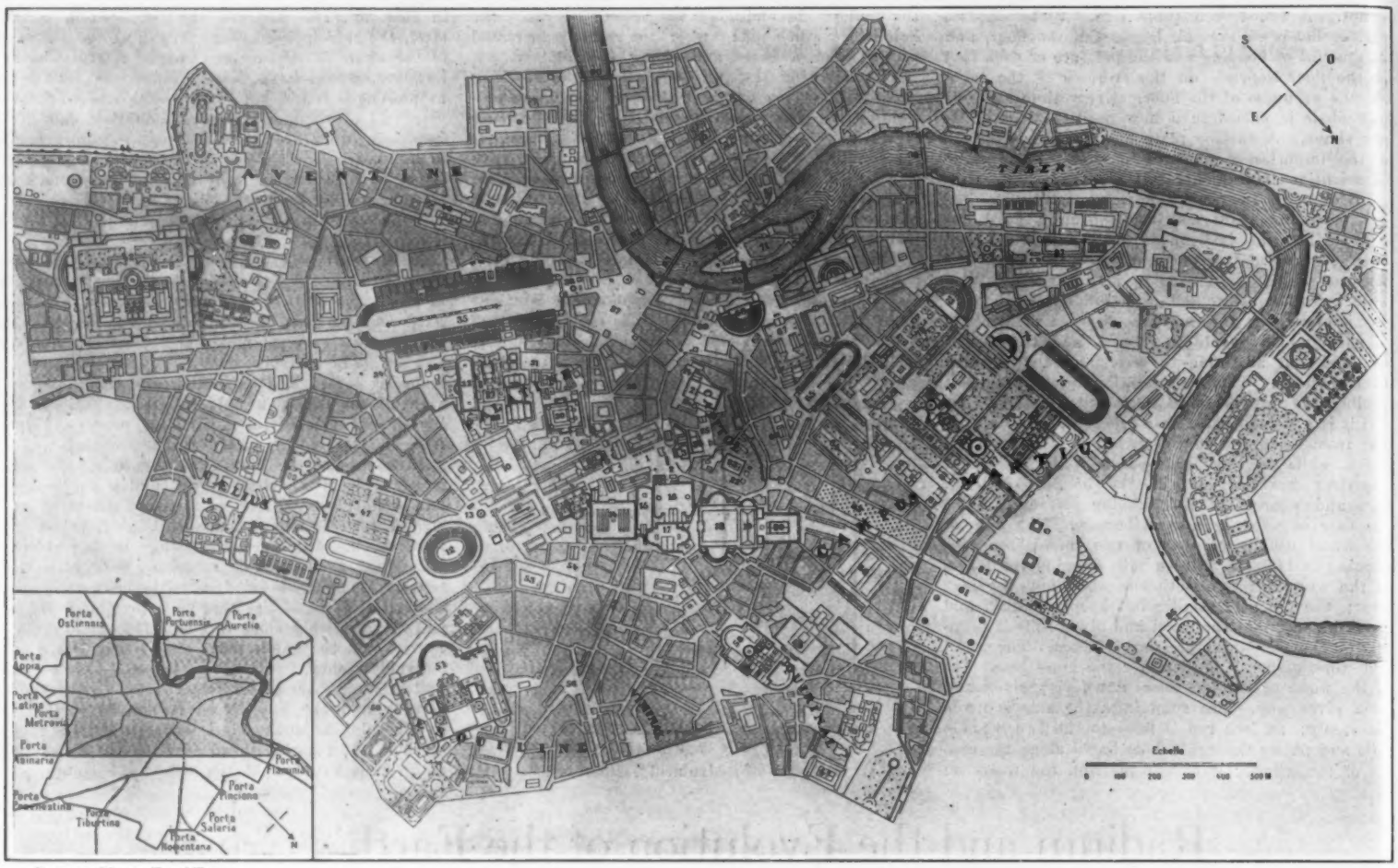
Carboniferous	340	million years.
Devonian	370	"
Ordovician	430	"
Algonkian	1,000	"
Archæan	1,000 to 1,630	"

We must not moan over the apparent difficulties with which the geologist has been faced since the advent of radium. Rather should they be welcomed in that they open the way for further advances. If at present some of our ideas are mutually incompatible, the discrepancies do not demand a wholesale rejection of the facts, but simply a re-interpretation of the fundamental hypotheses on which so many of our doctrines seem to hang.—*Nature.*

The Crossing of Water by Ants

John C. Willis, of the Rio de Janeiro Botanical Gardens, makes the following communication to *Nature:*

"It may not be new to observers of animal life, but I have been much interested in watching the common house ant here. We have an American fly-trap; the sugar was one day covered with ants, so I placed the trap on a finger-bowl standing in a plate of water. The ants, when they came to the edge of the water, ran round the bowl until convinced there was no way across, and then calmly "took to the water," and ran across it by aid of surface tension without getting their feet wet. Having presumably been home to the nest, they returned for more sugar, crossing in the same way, and this went on regularly, a steady procession crossing the water."



By courtesy of *Larousse Mensuel Illustré*

Rome in the fourth century. Key map of model shown on page 69.

I. THE FORUM DISTRICT.—1, Forum Romanum; 2, Comitium; 3, Temple of Concord; 4, Via Sacra; 5, Julian Basilica; 6, House of the Vestals; 7, Portico of the Jewelers; 8, Æmilian Basilica; 9, Basilica of Constantine; 10, Temple of Jupiter the Avenger; 11, Temple of Venus and Rome; 12, Colosseum (Flavian Amphitheater); 13, Arch of Constantine and Meta Sudans. II. IMPERIAL FORA.—14, Forum of Peace; 15, Nerva's Forum; 16, Caesar's Forum; 17, Forum of Augustus; 18, Forum of Trajan; 19, Ulpian Basilica; 20, Temple of Trajan. III. CAPITOL.—21, Temple of Jupiter Capitolinus; 22, Citadel; 23, Temple of Juno Moneta; 24, Tarpeian Rock; 25, Asylum; 26, Tabularium. IV. PALATINE HILL.—27, House of Augustus; 28, Temple of Apollo; 29, House of the Flavians; 30, House of Tiberius; 31, Temple of Jupiter the Champion (*Propugnator*); 32, Stadium of the Palatine; 33, House of Severus; 34, Septizonium; 35, Circus Maximus; 36, Great Altar of Hercules; 37, Forum Boarium (Cattle Market); 38, Velabrum. V. AVENTINE.—39, Temple of Diana; 40, Thermæ of Sura; 41, Via Nova; 42, Baths of Caracalla; 43, Fourth Cohort of the Civic Guard; 44, Wall of Aurelian; 45, Appian Way. VI. CELIAN.—46, Porta Capena; 47, Temple of Claudius; 48, Great Market; 49, Camp of the Wayfarers. VII. ESQUILINE.—50, Part of Nero's Golden House; 51, Baths of Trajan; 52, Baths of Titus; 53, Prefecture of the City; 54, Carinæ; 55, Argiletum; 56, Suburra. VIII. QUIRINAL.—57, Temple of Quirinus; 58, Baths of Constantine; 59, Temple of Serapis (or the Sun). IX. CAMPUS MARTIUS.—60, First Cohort of the City Watch; 61, Portico of Vipsania Polla; 62, Flaminian Way; 63, Sæpta Julia; 64, Portico of the Gods; 65, Flaminian Circus; 66, Temple of Bellona; 67, Portico of Octavia; 68, Theater of Marcellus; 69, Vegetable Market; 70, Theater of Balbus; 71, Tiberine Island (*Insula Tiberina*); 72, Temple of Aesculapius; 73, Pompey's Theater; 74, Odeon; 75, Stadium of Domitian; 76, Nero's Baths; 77, Pantheon of Agrippa; 78, Baths, Gardens and Pond of Agrippa; 79, Pompey's Portico; 80, Temples of Isis and Serapis; 81, Temple of Minerva Chalcidice; 82, Temple of Marcus Aurelius; 83, Sun Dial; 84, Altar of Peace; 85, Mausoleum of Augustus; 86, Marble-cutters' Workshops; 87, Stables of the Circus, 88, Trigarium (Training Ground); 89, Mausoleum of Hadrian; 90, Bridge of Theodosius; 91, Bridge of Probus; 92, Sublician Bridge; 93, Aemilian Bridge; 94, Cestian Bridge; 95, Fabrician Bridge; 96, Aurelian Bridge; 97, Nero's Bridge; 98, Aelian Bridge.

The Rome of Constantine*

The Ancient Capital Reconstructed in a Model Thirty-six Feet Long and Twenty Feet Wide

UNQUESTIONABLY one of the most attractive objects in the great Italian Exhibition at Rome, not only for archæologists and artists, but also for all intelligent people who care anything for the past, was a relief, or model, map of imperial Rome which was exhibited in one of the rooms of the baths of Diocletian. In an article describing this remarkable piece of modelling, M. André Baudrillart, writing in *Larousse Mensuel* for May, 1913, congratulates his fellow-countrymen on the fact that the artist, M. Paul Bigot, is a Frenchman, and a former *pensionnaire* of the Académie de France. The elaboration of such ideal restoration of ancient Roman monuments, says M. Baudrillart, has long formed part of the regular exercises of the architectural students of the French Academy in Rome, but done on paper and, hitherto, representing only one monument, or group of monuments —Roman, Greek, Sicilian, or even African. It required remarkable enthusiasm and audacity to attempt the task of reconstructing the appearance of a whole city—and that such a city as the Rome of Constantine. M. Paul Bigot possessed both these qualities, and it must be confessed that he has succeeded. It detracts nothing from the merits of the artist that the moment was well chosen for his enterprise. He had the numberless works of his predecessors ready to hand, and could select from them judiciously—the magnificent plan of Rome edited by Lanciani, the maps of Huelsen and Kiepert, the Abbé Thédénat's fine work on the Forum Romanum, Homo's useful Lexicon of Roman topography, and many other works besides, the crowning results of a century of ceaseless efforts, and especially of the last forty years, which have been so productive of methodical excavations and researches of all kinds. But to utilize all this demands much science, much address, much patient labor and, over and above it all, artistic comprehension.

The initial question to be decided was as to which period in the monumental history of Rome should be chosen for reproduction. Rome changed considerably in the course of ages. The Rome that echoed to Cicero's eloquence was not to be despised; still, considered from the artistic point of view, it presented comparatively slight inducements. In the Rome of Augustus—the marble city which he left, where he had found it brick, the central point, on which the eyes of the world are fixed, is no longer the Capitol, nor even the Forum, but the Palatine, where dwells the master of the world, and where imperial palaces were destined to rise after his time. But then in his time these palaces did not yet exist, and in a reproduction of that date a vast mass of triumphal arches, grandiose baths and ampitheaters, and imperial fora would be missing. The middle of the second century, to be sure, would have offered the double advantage of a classic Rome, complete and possessing a superior quality of art. But it is not difficult to guess why M. Bigot passed over all these and finally settled upon the fourth century.

Historical evolution was not the only factor in the modification of Rome's monumental aspect: no capital, perhaps, was ever more frequently ravaged by conflagrations, which made room for new buildings. Under Nero, three out of fourteen districts of the city were totally, and seven more (and those not the least beautiful) almost totally, burnt out. And although this was incomparably the worst catastrophe of the kind, in the reigns of Titus, Antoninus, Commodus and Carinus, Rome was afflicted with severe losses by fire. On the other hand, the fourth century presents the last state of imperial Rome. In that century great edifices rose: the basilica of Maxentius, which bore the name of Constantine because the latter emperor inaugurated it; the arch and the baths of Constantine. It was then that the highest obelisk in Rome was erected in the Circus Maximus. Soon after this, the emperors deserted Rome, the public treasury was impoverished, the city was depopulated, the hordes of Alaric and Genseric plundered it, the temples were empty of worshipers—all these causes combined to effect the monumental decay of Rome. The Rome of Theodoric, indeed, is still very beautiful, with its outburst of Christian architecture, its mosaics and its new style of decoration. But while this later Rome offers a wide field for the study of the thinker and the admiration of the artist, it is no longer quite the ancient Rome, the pagan Rome, which subjugated the world. In spite of signs of decadence revealed in some of its latest works of architecture and sculpture, especially the latter, the monumental aspect of the city attains, as M. Bigot says, its full development in the fourth century. And this epoch was found to be the only one the ruins of which afforded a solid basis for M. Bigot's reconstruction: the part to be played by imagination and conjecture is still considerable, but it would have been much larger for any other period.

For the architect, as for the palæontologist, a fragment of remains is often rich in revelations, and what is to the average man an uninteresting piece of stone will enable the expert to find the scale, the dimensions and even the date of a monument, and to identify it. What, for instance, Homolle and his assistants have done for Delphi may in many respects be compared to the work of Cuvier, who from a fragment of a molar, or of any other characteristic portion, could deduce the genus and species of an extinct animal. And Rome has, proportionally, preserved much more for us than Delphi.

The relief map shows only a little more than half of the whole city, but this half is the heart of it. Of the the his-

* Abridged translation from *Larousse Mensuel Illustré*

By courtesy of *Larousse Mensuel Illustre*

Rome in the fourth century.

The relief, or model, map of Rome in the fourth century, the central portion of which is reproduced here, is about 70 quare meters in area (11 meters by 6.35 meters). The key map (see page 68) will enable the reader easily to find the chief monuments of Rome. The above perspective throws some of hem into especial prominence: along a horizontal line half way up on the plate, the imperial *fora;* toward the right, between the roof of the Ulpian basilica and the Temple of Trajan, may be seen the top of Trajan's column. Above this line is the Forum Romanum, where seven white columns rise in front of the Julian basilica; from here, though hidden behind the basilica of Con tantine and the Temple of Venus and Rome, runs, on the left, the Via Sacra, toward the oval bulk of the Colosseum. Below, o the left, are the baths of Trajan. Above, on the same side, two great aqueducts (the Marcian and the Claudian), and between them the elongated shape of the Circus Maximus, in front of which the buildings on the Palatine are outlined as far as the line of the Via Sacra and the Forum. To the right the Forum Rom num ends in front of the ascent of the Capitol, which is seen in he quadrilateral defined by the theater of Marcellus, the Forum Romanum, Trajan's forum and the Flaminian Circus. On the double summit of this hill the temple of Jupiter Capitolinus may be distinguished above, and that of Juno Moneta below. At the top of the plate, a little to the right of the middle, is the Tiberine Island, the theater of Balbus, the theater and portico of Pompey, the Odeon, the Thermæ, and Agrippa's Pantheon. Lower down, below the Via Flaminia, which is interrupted near he column of Marcus Aurelius, the barracks of the First Cohort of the City Watch (Police) are distinguishable by their three courtyards, also the temple of Serapis (or the Sun), and the baths of Constantine, with the central cupola.

toric spots and the great monuments, none is missing except the immense baths of Diocletian, the ruins of which, all crumbled as they are, are still a source of astonishment. Nor do we see the Prætorian Camp, which no longer existed after Constantine's time. Without broaching archæological controversies, which are of interest only to specialists, we may go through the city as it is given in this relief, for in the broad lines of its principal monuments, Roman topography has been so carefully studied as to be finally settled.

The Romans were deeply attached to the scenes that were the witnesses of their earliest origins, of the national legends in which they retained but little belief, but which, nevertheless, were piously transmitted from generation to generation. On stormy days the slopes of the Capitol still resounded with the plaintive howlings of the she-wolf which the descendants of Romulus kept in the thickets of that glorious hill in memory of their ancestor's nurse. And instinctively, as we look at this cold image of departed Rome, our eyes turn to the Capitol. No portion of the city presents in so small a space—a circuit of 4,000 meters—such an accumulation of majestic monuments so sumptuously adorned. Our route takes in the Capitol, the Palatine and the Colosseum, and comes back by the monuments which line the space between the Colosseum and the Forum proper; then it turns to the right, tracing the sites of the imperial fora, passes behind the temple of Trajan, and returns to the Capitol at the temple of Juno Moneta. Indeed, leaving aside the Campus Martius, where the elections used to take place under the Republic, all Roman history, republican and imperial alike, is embraced in this small circumference. Here statues, altars and columns jostle each other. The sites are relatively small: the Forum, ever since the heyday of Roman eloquence, has been of very limited dimensions. But what intelligent harmony, what happy arrangement! It is the most ingeniously combined world of stone, for the delight of the eye, that could possibly be imagined. Nothing seemed too fine to deck the cradle of Rome. Nature herself had to yield place to human will. The caverns of the Palatine were shut in behind the enormous substructures designed to extend the hill so as to support the palace of Caligula on one side and that of Septimius Severus on the other. The Velia, a prolongation of the Palatine Hill, was cut down, and the Arch of Titus, rising upon the summit of a gentle slope, marks its culminating point, which is certainly much lower than it was under the Republic. A causeway across the marshes formerly connected it with the Capitol—the origin of the Via Sacra. These marshes, which separated the Palatine from the Comitium, have disappeared beneath the thick pavements under the Julian and Aemilian basilicas, the temple of Castor and Pollux, the House of the Vestals and other structures: a few pools, such as the elegant fountain of Diuturnus, which was discovered about ten years ago, merely serve to mark their position.

Looking upon all this multitude of temples, basilicas, porticoes, triumphal arches, one sometimes feels inclined to ask, where did the people live—a population of at least two millions? Certainly not here. It is true that these very buildings sheltered, especially those of the Palatine, a fairly large population of priests, janitors and other functionaries, and we know that except the *grands seigneurs*, the ancients were not very exacting in the matter of lodgings. But if we look at M. Bigot's reconstruction, outside of this district reserved for monuments of religion, art, history and politics, there is no lack of dwellings between the walls of Aurelian, where the narrow streets and the tall houses are crowded together, and the poorer sort of people are heaped up, just as the Italians of to-day swarm in the old quarters. Even around the public monuments private houses crowded. Tacitus tells us that in 68 the soldiers of Vitellius, when they attacked the Capitol, came as far as the temple of Jupiter through a number of houses, the last of which reached as high as the platform at the top of the hill.

The Forum was inclosed between the three hills of the Capitol, the Palatine and the Quirinal. Only the first and second of these dominated it, separated by the hollow of the Velabrum, which led from the public plaza to the lower quarters bordering the river, and allowed the river to flood the Forum on occasions of great overflows. Nowadays it is the picturesqueness of this setting that strikes us; then, it would have been the grandeur. To the south, the Palatine, covered with palaces, temples and gardens. In the middle was the house of Augustus. The first emperor was born on that hill, and when he returned to it from Actium he may have remembered that kings had lived upon it. But there was nothing sumptuous about the house of Augustus: as we know, he hated pomp in his surroundings. He reserved all his efforts for the magnificence of the city and for the worship of the gods, whose prestige he desired to restore. He had joined to his own dwelling, too, a great temple dedicated to Apollo. He had thrown open to the educated public a Greek and Latin library. Vast in a different way and truly imperial was the palace (*Domus Tiberiana*) built by his successor, Caligula, who had grandiose ideas, and confounded astonishment with admiration still further enlarged by means of insensate works. Conceived on a great scale and, we may be sure, in sounder taste, was the fine palace of the Flavians, the remains of which cause us to admire unreservedly its elegant proportions and happy arrangement. The boldest of the constructions of Septimius Severus was the Septizonium, a sort of decorative front, at the southern boundaries of the Palatine, presenting three tiers of columns facing the Appian Way. On this proud hill the masters of the earth had the master of heaven for a neighbor: Jupiter, under the surnames of Champion, Avenger and Conqueror, was the most petted guest, and three temples dedicated to him attested the gratitude of the people and their chiefs. A temple of Cybele rose at the western angle; and not far off, its lowliness contrasting with the neighboring splendors, and recalling the humble beginnings of Rome, was the hut of Romulus, carefully preserved down to the end of the Empire. National pride, far from blushing for it, delighted in measuring at a glance the long road from a chieftain of disciplined shepherd-brigands to the all-powerful Cæsars. The Palatine could show, also, the grotto where the overflowing Tiber deposited the twin sons of Mars and Rhea Silvia; it was called the Lupercal, and was consecrated to Pan.

But, for all these archaic memories of rustic beginnings, the true historical evocation of the Palatine is chiefly the Rome of the Cæsars. The Capitol, on the other hand, palpitates with the life of Rome whole and entire; it is *par excellence* the sacred and venerable hill. Here, in a temple more august than all others, the Capitoline triad, Jupiter, Juno, Minerva, watched over the destinies of Rome. Thrice was this temple burnt, and thrice did Rome hasten to rebuild it. The first time, under the Republic, and the third, in the reign of Titus, the conflagration was accidental; the second time, in the rising which overthrew Vitellius in favor of Vespasian, it was caused by the partisans of Vespasian, to repel the attack of the Vitellians. "It was," writes Tacitus, "the most deplorable and shameful catastrophe that Rome has known since her foundation. The city had no enemies without, and was at peace with the gods; and this dwelling-place of great Jove, founded by our ancestors, upon the faith of the auspices, as the pledge of empire, this temple the sanctity of which neither Porsenna could violate, when the city surrendered to him, nor the Gauls, when they seized it—Rome saw this temple perish in the mad quarrels of her own princes." Thus does the very conscience of Rome utter itself by the pen of the Roman historian. Isolated within its own inclosure, defended by natural escarpments—one of them the famous Tarpeian Rock—with its two crests separated by the hollow where the wood of the Asylum long flourished (the refuge opened to all comers by Romulus), the Capitol was not only the holy city, but contained the almost impregnable citadel. There, too, was the temple of Juno Moneta (the Admonitress), whence we have our word *money*, a reminder of the first mint, which was set up by the Romans in the purlieus of this sanctuary.

Many were the legends connected with the Capitol. The southern end preserved the memory of Saturn, who, according to popular tradition, was the first king of Latium. A Greek colony, connected with that which Hercules had brought to the Palatine, was supposed to have existed there, and hence the name of *Saturnia*, borne by that part of the hill. The head (*caput*) found in digging the foundations for the temple of Jupiter originated the name of *Capitolium*, which was afterward extended to the whole quarter. In the Capitol the Senate held its first session every year and it met there on occasions of more than ordinary importance; there the magistrates offered a solemn sacrifice when they entered upon office, and from there they set out to assume the government of provinces or the command of armies; it was the terminus of every triumphal procession, the essential feature of which was the sacrifice offered in the temple of Jupiter Capitolinus, and there were deposited the texts of treaties concluded with foreign kings. Lastly, this sanctuary of religion and last rampart of defense was also the place of expiation of the most heinous crimes, for the greatest criminals were precipitated from the Tarpeian Rock.

The Middle Ages, which so strangely distorted the memories of antiquity, thoroughly preserved the sentiment of the place's sacred character. While the Forum was covered with rubbish, and the palaces of the Cæsars crumbled or became a stone quarry for the benefit of all comers, the Capitol remained the political center of the city. It is still the seat of the Municipal Government. In the Middle Ages people imagined it, as Rodocanachi tells us in *Le Capitole antique et moderne*, to have been a splendid palace, glittering with gems and roofed with glass, worth one third of the whole world's wealth. And one of the emperors had placed in one hall of it a semicircle of statues representing the various races descended from Noah which had been subjugated by the Roman Empire; each statue had a bell fastened to its neck, and when one of these bells rang a revolt was imminent in the country represented by that statue, and the priests who watched day and night in the hall immediately gave warning to the Senate. The inventor of this wonderful safety apparatus of the Empire was supposed to have been no other than Vergil, the great magician, whose mighty magic for telling fortunes was still reverenced in the fourteenth century. Another form of the legend substituted for the statues a bronze man on horseback, who from the top of the Capitol watched over the whole world; and if any danger threatened Rome, he turned like a weathercock toward the quarter whence the danger was arising. Or again, there was the story of the mirrors in which interesting events were reflected. Thus was the power of Rome explained when it had been magnified in the imaginations of her degenerate sons.

But Rome was not merely a city of traditions; it was a city where people worked—in spite of the exaggerated *panem et circenses* idea—and ate and enjoyed themselves. Nor was it only the slaves who worked. Free labor, which was never completely annihilated at Rome, constantly grew under the Empire. From the time of Augustus the number of slaves seems to have decreased. Beginning with Diocletian, free labor was organized in corporations. The supervision of labor, labor itself and the commerce which handled its products, occupied a host of freedmen, *bourgeois* and humble citizens. The same with bureaucratic work. Monumental Rome could not but bear some testimony of all this activity. In the Forum itself we have the *Porticus Margaritaria*, a great covered bazar, where the jewelers displayed their seductive wares. Also in the Forum, in the Julian and Aemilian basilicas, were money-changers. In the capital of the Empire so many various coinages came together that the handling of them became a puzzling matter, and this business demanded special and very wide knowledge. The Velabrum was a commercial quarter. Although we cannot penetrate into its shops, here, at any rate, a few steps from the old Forum, is the vegetable market, to which the market gardeners daily brought their fresh produce; and, no doubt, the hunters, their game trapped in the mountains and woods of Etruria and Samnium, as certainly the farmers brought their milk. M. Bigot has been able to indicate with certainty a very small monument in the vegetable market which is not without interest—the "milk column," at the foot of which, according to some authorities, abandoned infants were deposited on the chance of being picked up by some kind person, or else by some slave-merchant. More probably the babies were taken there to be given some of the fresh milk just brought in from the country. A little way off was the cattle market (*forum boarium*), where beasts for slaughter were bought and sold, particularly pigs. Pigs supplied a large part of ancient Roman alimentation, and the *suarii*, whose part it was to supply the pig-market, formed an important corporation, bound by strict obligations and also enjoying privileges and honors. On the edge of this *forum boarium* was the most important of the food institutions, the *statio annonæ*, which existed for the purpose of insuring to Rome its daily supply of grain from Italy, Sicily and Africa. We know that it was sold at a state-regulated price and, in part, distributed *gratis* by a prefect of the grain-supply. When the tottering government was no longer able to discharge these duties, the "Granaries of St. Peter" supplied its shortcomings; and this was one of many services which habituated the people of Rome and its environs to regarding the Pope as their true sovereign.

Between the Stadium and the Tiber was a vast marble-shed, where stonecutters and marble-polishers exercised their craft. Their tools are sometimes found there, and not many years ago one might still see half-hewn blocks and other evidences of the industry which must have been so considerable for many centuries.

As for intellectual work, Rome had become a great university town. If we cannot point to the buildings where advanced learning was distributed, this map-model shows us, in their places of honor, the palace library and the two libraries, Greek and Latin, near Trajan's Column behind the Ulpian basilica, at the end of the imperial fora. Of these latter we must still admire the chiseled stones of the forum of Augustus, accurately superimposed, without the help of cement, and the fine sculptures of the temple of Minerva Medica.

The baths were associated at once with hygiene, intellectual life and the grosser pleasures. When manners became softened, the Roman epidermis became more delicate. The old-fashioned plunges in the Tiber of earlier generations gave place to the *thermæ*, or hot baths, and a great number of buildings for this purpose sprang up, some for the rich, others for the poor. They became the centers of fashionable life—restaurants, libraries, music halls and lecture rooms became their necessary accessories. Nothing pleased the masses more than the opening of such an establishment. The emperors took care not to neglect so efficacious a means of gaining popularity. All the resources of art and luxury combined to render the baths more and more attractive. Nothing, perhaps, astonishes tourists more than the baths of Caracalla (*Thermæ Antonianæ*) along the Appian Way, beyond the Circus Maximus. Near the Colosseum

we can see baths of Titus, of Trajan and of Constantine on the Quirinal, and of Agrippa and Nero in the neighborhood of the Pantheon. It must have cost a great deal to build them.

As a city of pleasure, however, Rome was not to be compared to Paris. And we have already pointed out that it was also a working city. Indeed, it must have taken much work to support such an organism, though one is apt to forget that truth. We are too apt to judge of Rome as foreigners judge of Paris, when they lose sight of the Institut Pasteur behind the Moulin Rouge. The monuments of pleasure in Rome of which one thinks first are just those which strike the eye in going over this relief of the city: the Colosseum and the Circus Maximus. The former is the most enormous of amphitheaters, and it owes still more of its celebrity to the Christian martyrs than to its size. No ruin has inspired so much fine literature. Moreover, it has been the model of much Renaissance architecture. The Circus Maximus was the chariot race course. It was very ancient, for, according to the tradition, Romulus held on its site those games in the course of which the Sabine women were carried off, and it began to be fitted with seats in the time of Tarquin. After that it grew constantly, until, at the end of the Empire, it is said to have accommodated 350,000 spectators. The Colosseum held at least 50,000. We are told by contemporary writers that, when the races were going on, the rest of the city appeared deserted, and thieves seized the opportunity. It was for this reason that the emperors doubled the patrols of police (or the city watch, whose barracks we see on the map) throughout the streets. During these races, too, fires were particularly frequent, either through malicious arson or through thieves who profited by the consequent confusion to loot. The city watch (*vigiles*) were both policemen and firemen.

The games were religious in origin, though their religious character became attenuated, without ever quite disappearing. They were preceded by a solemn procession through the Via Sacra to the Circus. In this procession images of the gods were carried, to be deposited, while the games went on, on the splendidly decorated *Spina* which divided the Circus lengthwise, as indicated in the map.

Most of the places of amusement were on the Campus Martius and along the Tiber, a little way down the course of the river. On the Campus were Pompey's theater, the Odeon and the Stadium. At the first of these, as at the theater of the Balbi and that of Marcellus, tragedy and comedy were played, and particularly, in the imperial age, pantomimes. Tragedy, appreciated only by literary people, was read more than acted. It is probable that public readings were given at the Odeon, which was built especially for a select public, and served as a concert hall. The Stadium, now the Piazza Navona, was given up to foot races and gymnastics. There were other stadia, notably one, still in fairly good preservation, adjoining the palace of Septimius Severus on the Palatine. The gladiators were lodged and trained in barracks (*ludi*) of which there were four in imperial Rome. The *Ludus Magnus*, a little beyond the Colosseum, and the *Ludus Dacicus*, some distance from the baths of Trajan, are here indicated. Some idea of the number of gladiators may be gathered from the facts that Otho incorporated 2,000 of them in his army; and Dio Cassius says that 10,000 of them fought in one series of exhibitions.

The Spirit of Invention*

The Keynote of Our Modern Age

By F. W. Parker

We are told by great authorities that there is not very much difference between the present and ancient times in respect to literature, philosophy and the fine arts, but with respect to invention of mechanical devices the difference is immeasurable. Thus, it might be said of Greece that she had everything but invention, while invention so far dominates with us that an unthinking person might say that we had nothing but invention. Whatever the nature of the inventive process, it is therefore certainly the last faculty to be developed, and we are the fortunate beholders of a vast flowering forth of the human mind in a field until recently almost uncultivated. All the mechanical inventions of all the ages and all the nations to a very recent period would be to the inventions of the last seventy-five or one huudred years about what a yard of calico would be to the contents of a great modern retail establishment. No one has yet propounded any very satisfactory explanation of the absence of mechanical invention among the Greeks and Romans. The late development of the inventive spirit may be due simply to the fact that it is the highest and most difficult of intellectual activities. It is easier to bow before a force of nature than to invent an apparatus which will dominate it. It requires less effort to worship the sun than to devise and use a means whereby it may be understood for what it is. It is easier to fashion some kind of a theory of the universe or a religion than it is to create a steam or gas engine.

The very lateness of this development suggests that it demanded the highest form of mental activity. This is true if we are to believe in human progress. If the Reindeer men were in effect great artists, if successive civilizations have left us, as in the Greek Archipelago, superimposed remains each of which is rich in art relics while all are destitute touching mechanical inventions, it may be because art production has required a lower form of mental activity than mechanical invention. If all savage tribes have their rude systems of philosophy and every civilization has eventually worked out a profound and complete system while until now developing no mechanical inventions, it is perhaps because such activities call for a lower type of mental activity. If all such activities of the mind as have to do with art, literature and philosophy are lower than the activities of invention, it is perhaps because they are not really creative and because they are not limited to the use of fixed, unyielding, unchangeable elements and they do not, therefore, lead readily to what is novel or result in the establishment of what is true. Worse than all, they do not give man confidence in his own ability to solve his own problems by his own activity. On the contrary, they for the most part teach him first to admire, venerate, and copy what his remote ancestors did, and then to rely upon the help of various external agents. It is in inventive activities that the mind comes upon solid ground and it then proceeds with confidence toward all forms of speculation which are aided and supported by invention.

Now note that there is a steady drift of human interest away from these other activities and toward the mechanical arts and the inventive processes of the mind. This is noticeable in the attitude of the modern boy. A few decades or a century or two ago, he was wondering about the mysteries of the wind, the waves and the stars, speculating upon the spirits of the caves and the forests, and waking up in the night shaking with fear on account of the demons he had seen. Now he spends most of his time talking about locomotives, engines, flying machines and submarine boats. Do not tell your friends too much or with too much enthusiasm about your young son's wonderful mechanical or electrical achievements, for when you do, you only write down your own ignorance and report the fact that your son is simply a common-place boy, for that is what all boys do. Two little eight-year-old boys of my acquaintance spent the whole of last summer making a wagon out of an old rolling chair, an alarm clock, a broken lamp and various scraps which they picked up in a wood shed. The finished wagon had an alarm signal, a headlight and brakes. The significant thing in what they did was this: as soon as they got one part done, for instance, the brake, they immediately began to better it, and they made several successively better brake mechanisms.

This drift of the adult's mind toward mechanical things can easily be noted. Men affect a knowledge of mechanics which they often do not possess; they affect an interest in mechanical things which they do not understand; they simulate the mental habits of inventors and engineers and creators. Men quite unlike inventors, engineers or mechanics commonly talk invention just as the Greeks in imitation of Alexander wore their heads tilted to one side and as the Germans imitate the Kaiser's mustache.

In an industrial community this tendency toward interest in the inventive mental activity is very noticeable. Contrasting an art community like Paris with an industrial community like Chicago; a few years ago I carefully examined eleven Parisian newspapers containing 6,670 inches of reading matter and nine reviews of magazines containing 787 columns of matter. These I purchased on one day. Not a line did I find which could be fairly classified as relating to invention or manufactures, industry or commerce as affected by inventions, except about 65 inches in a socialistic paper. There was nothing about the mechanics of railroads, telegraphs, telephones, manufacturing or invention, but an immense amount of good material about art, music, history, literature and philosophy. Now look at a group of metropolitan morning papers, with these facts before you, and you will note the same contrast that I noted.

May not this general drift of mind in boy and man and nation and period be due to the fact that in the mechanical arts and inventive processes the mind feels itself on safe and solid ground? The mind in following the inventive processes is engaged in a purely creative undertaking. It is limited by real and inelastic things. Its goal is truth. It leads necessarily to a maximum of self-reliance and a minimum of reliance on others. It, therefore, inevitably sweeps away the false props on which the mind theretofore delighted to lean. It is the latest and probably the highest type of intellectual activity, and as a mode of mental motion tends to dominate all mental activities and become the universal type. This is true because of the aggressive nature of invention. It declares with respect to every part that all that is, is not the best; that perfection in anything is unattainable; that action alone is good because action means progress; it sets itself in direct opposition to the doctrine of Nirvana so long the opiate of India. It asks for no period of eternal rest. It is never satisfied with a copy of anything. It knows that everything can be made better because everything that invention has touched has been made better. The goal of invention for this world as for the next is not "What shall I be?" but "What shall I do?" If invention studies nature or the origin of things and the qualities of elements, it is with no dreamy expectation of any purely metaphysical result but that it may better understand the physical universe and its elements to the end that they may be better combined and utilized under the processes of invention for the benefit of man. The inventive spirit is an attack on the classical because it is old, and on the romantic because it is too often unreal. With invention there is no room for an inefficient or untruthful product. The inventive movement is sometimes spoken of as a conflict between efficiency and beauty. Should they not, however, agree, as they do, for example, in the human body or in the prow of a ship, which may be contrasted both for beauty and efficiency with the bow of a scow? Not to have attained something of a true sympathy for this inventive spirit is to have joined the passivists, and those who drift instead of those who create.

* Excerpt from a paper read before the University of Chicago.

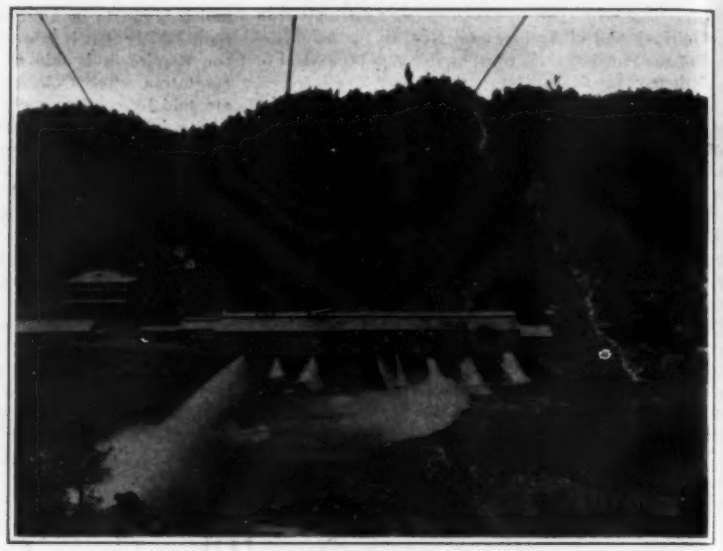
Dead Ammonia

The term "dead ammonia" is frequently applied to anhydrous ammonia that has become contaminated by refrigerating oil or perhaps water drawn into the system. The effect of these impurities is to raise the boiling point of the ammonia so that it is sluggish in evaporating out of the impurities at the usual back pressure.

By drawing a sample of such impure ammonia from a pipe coil or storage tank it will be found that when evaporation ceases the impurities will have deposited in the vessel used for the purpose. This is a good way to determine how much the ammonia has been adulterated.

There are, of course, ammonia purifiers on the market into which the impure liquids, generally found at the bottom of the receiver, are drawn. By means of a small amount of steam this liquid can be heated and the anhydrous ammonia returned into the suction line. The impurities are collected in the purifier and may be blown off. Another type of purifier not only takes the liquid from the receiver but also purifies the suction gas before it enters the compressor. Both systems are useful in connection with refrigerating and ice-making plants as they will eliminate the so-called dead ammonia. —*Power.*

The Colgate flume—over seven and one half miles long.



Hydro-electric power plant at Colgate.

Hydro-Electric Development in California

A General Survey of the Present Situation

By John A. Britton

A GLANCE at a map of California similar to that accompanying this article, on which is portrayed the veritable network of long-distance transmission lines that mark the course of hydro-electric development from end to end of the State, might convey to one not acquainted with actual conditions, the impression that there is but little left undeveloped of the sources of water-power with which this wonderland of the West abounded when first adventurous man started out in his now far-reaching enterprise among the head-waters of our mountain streams.

This impression has, indeed, been circulated widely by those who in pursuit of a policy of so-called conservation would hinder the development of California's natural resources, and so, her progress and advancement. What foundation it has in fact may be gathered from certain statistics to hand. Mr. M. O. Leighton, Chief Hydrographer of the United States Geological Survey at Washington, in an article on "Water-power in the United States," published in the May number, 1909, of the *Annals of the American Academy of Political and Social Science*, writes: "The water-power plants in the United States make productive use of only 5,500,000 horse-power, less than one fortieth of that ultimately available." The report of the United States Geological Survey upon California, published March, 1912, gives the following figures for our State:

Potential horse-power development on a basis of 90 per cent efficiency; minimum 4,109,000, estimated maximum 9,382,000; on a basis of 75 per cent efficiency, minimum 3,424,000, estimated maximum 7,818,000.

And the total amount of water-power development in the State of California to-day stands at, in round numbers, 450,000 horse-power!

It is safe to say, however, that this total bids fair to be materially increased within a very short while. Important developments are now in process of construction, a very necessary undertaking in view of the rapid increase in California's population, an increase which undoubtedly will mount by leaps and bounds when the great International Exposition to be held in San Francisco in 1915 brings visitors from all parts of the world to view the marvels which Dame Nature has heaped with so lavish a hand on our Golden State. And so we should congratulate ourselves, perhaps, that the development of our natural resources is yet only in its infancy. It reveals California as a land of infinite possibilities, where there is room and plenty for all who come to settle in her spreading valleys, and by their enterprise and energy help to place her where she belongs among the great States of the world.

As matters stand at present it may be said that the water-power development of California is controlled, to the extent of something like 86 per cent, by seven large corporations. The largest and most comprehensive of these, of course, is the Pacific Gas and Electric Company, which operates over thirty counties in the State of California and has a present hydro-electric development of about 91,000 horse-power. The next largest is the Great Western Power Company, operating also in a large portion of northern central California, with 53,000 horse-power; the Sierra and San Francisco Power Company, covering a portion of the same territory, with 50,000 horse-power; the Northern California Power Company, operating, as its name would suggest, in the extreme north of the State, with 45,000; the Southern California Edison Company, operating in the territory around Los Angeles, with 38,000; the Pacific Light and Power Corporation, running over almost the entire territory from Tehachapi to the southern border, with about 20,000; and the San Joaquin Light and Power Corporation, operating in the San Joaquin Valley and making a sort of connecting link with the Pacific Light and Power Corporation, with about 25,000 horse-power.[1]

There are some smaller companies also worthy of mention here, as, for instance, the California-Oregon Power Company, one of whose water-power plants lies within our State limits and has a 9,000 horse-power capacity; the Oro Electric Corporation, operating in the Sacramento Valley, which has a present installed capacity of 4,000 horse-power; the Western States Gas and Electric Company, controlling the distributing system in and around the City of Stockton, with a similar amount; the Snow Mountain Power Company, in the Eel River District, with 3,000 horse-power; and the Mt. Whitney Light and Power Company, operating in the neighborhood of the oil districts, with 8,000.

Let us start, if you please, at the northern boundary of California and travel down through the State, taking in the various hydro-electric developments as we reach them and sketching briefly the organization and operating system of each, with such improvements and extensions as are known to be either in process of actual construction or in contemplation for the immediate future.

We begin with the California-Oregon Power Company, which operates in both States named. This is an amalgamation of the Siskiyou Electric, Rogue River Electric and Klamath Falls Electric Power Companies and was organized in January, 1911. Its territory ranges from Merlin, above Grant's Pass, in Oregon, on the north to a point about ten miles south of Castella, in Shasta County, California; an area of about 10,000 square miles. It has two power-plants located in California, one

[1] See SCIENTIFIC AMERICAN SUPPLEMENT, March 8, 1913, p. 152.

Dam and intake of canal on American River—Folsom power system.

Power plant at Folsom—the oldest in service.

General view of the hydro-electric plant at Electra.

Intake on the Feather River.

on Falls Creek, the other on Shasta River, both streams being tributaries of the Klamath River which rises in the mountains of Oregon.

Running across country in an easterly direction we strike a small system constructed by the North Mountain Power Company but now owned and operated by the Western States Gas and Electric Company. It is situated on the Trinity River, near Weaverville, and is of about 2,000 horse-power capacity. Then, due south, we reach the plant of the Snow Mountain Company, which takes its power from Eel River in the Mendocino County mountains. This company is strictly in the wholesale business and disposes of a large proportion of its output to the Pacific Gas and Electric Company, while purchasing during low water periods its supply from the same company, the balance to California Telephone and Light Company and other minor distributing companies.

Returning to Shasta County, the rapidly-inlarging system operated by the Northern California Power Company is reached. This company is a consolidation of companies beginning with the taking over of the Keswick Electric Power Company's plant in 1900. It owns three water-sheds located, respectively, on Battle Creek, Cow Creek and Burney Creek, all streams rising in the vicinity of Mt. Lassen. The system embraces five water-power stations, Volta, of 8,500 horse-power capacity; South, 8,000; Inskip, 8,000; Kilare, 4,000, and Coleman, 16,000 horse-power; total, 44,500 horse-power. The company has 258.43 miles of transmission lines at 22,000 voltage, and 126 at 66,000, distributing electric energy through the upper section of the Sacramento Valley, and reaching as far as Willows, in Glenn County. The Pacific Gas and Electric Company is a purchaser from the Northern California to the extent of 10,000 horse-power.

In the mountains of Butte County, northeast of Chico, we enter upon the spacious territory covered by the Pacific Gas and Electric Company's system. This is an amalgamation of power companies dating from the very inception of long-distance transmission of electric energy for commercial purposes in this part of the world, including the Bay Counties Power, Valley Counties Power, Standard Electric, Yuba Electric, Nevada County Electric Power, Butte County Electric Power and Light and Central California Electric Companies. These, with three water systems and fifteen distributing companies, formed the California Gas and Electric Corporation, which was incorporated in December, 1901. Four years later this comprehensive enterprise purchased the San Francisco Gas and Electric Company and reorganized under the name and style of the Pacific Gas and Electric Company.

This vast hydro-electric system stretches over a territory which, if superimposed upon a map of the far Eastern States, would start at about Albany, N. Y., and run all the way down to Philadelphia, Penn. At the present time its system includes eleven water-power plants, nine of which are in active operation, and its distributing lines cover an area of about 37,500 square miles.

Its most northerly plant is situated, as stated, northeast of Chico, on Butte Creek. It is named "de Sabla," after Mr. Eugene J. de Sabla, Jr., one of the founders of this great organization. The amount of energy generated here is about 17,500 horse-power under a head of 1,531 feet, and the water as it escapes from the power-house is taken up and used a second time under a head of 577 feet at a point called Centerville, eight miles down stream, where the installed capacity is 8,500 horse-power.

Southeast of this, in Yuba County, the Colgate power-plant is located on the North Fork of the Yuba River. This is one of the oldest of the large power-houses and was built in 1899 to convey electric "juice" to the city of Sacramento, and the original installation of 4,000 horse-power has since been increased to 20,000. The static head is 700 feet. It is named after Mr. R. R. Colgate, of New York, who at one time was a partner of Messrs. John Martin and Eugene J. de Sabla, Jr., in hydro-electric enterprises.

Some twenty miles to the east of Colgate is situated one of the company's earliest plants, on

Map of California, showing network of long transmission lines.

the South Fork of the Yuba River near Nevada City. It was built in 1896 to supply power to the mines, and has a present capacity of 533 horse-power under a head of 292 feet. Still further east, however, a useful plant is found located on Deer Creek, where there is an installed capacity of 7,350 horse-power under an 831 foot head. And a few miles to the southeast there is a 4,000 horse-power station at Alta, head of 660 feet, on the overland line of the Southern Pacific.

The company's largest hydro-electric plant at present in operation is that at Electra, in Amador County. The water for this is taken from the Mokelumne River and, also, from Blue Lakes, Meadow Lake and Twin Lakes, a chain of storage reservoirs in Alpine County, and the Bear River Reservoir in Amador County, and is conveyed by two canals, upper and lower, to a point on the Mokelumne River where there are static heads of 1,460 and 1,260 feet, respectively. The installation here is of 26,800 horse-power capacity. This is the company's show-plant, at present, having been expensively constructed by the Standard Electric Company in 1902, and inlarged in 1907 by the Pacific Gas and Electric Company.

The remaining power-plants belonging to the Pacific Gas and Electric Company are of lesser importance, save for the historical associations connected with that at Folsom, whence in September, 1895, the mysterious energy called electricity was first conveyed along high voltage wires to the City of Sacramento, 22 miles distant. This, indeed, marked the beginning of the great system operated by the Pacific Gas and Electric Company. The Folsom plant is still operated under heads of 55 and 27 feet, the supply of water from the American River on which it is located being sufficiently large to produce results.

But this aggregate of some 91,000 horse-power developed by the Pacific Gas and Electric Company from its water-power sources bids fair to take a big jump in the not far-distant future. Up in the high Sierras, where the company owns a chain of twenty-three lakes, there is construction work in progress which, when completed, will add no less than 160,000 horse-power, with an aggregate head of 4,370 feet, to the company's hydro-electric system. The work starts at Lake Spaulding, in Nevada County, near the summit of the Sierras, where a dam 305 feet in height is to convert the lake into a storage reservoir of 30,000,000,000 gallons capacity. From this the water is to be conveyed by tunnel and ditch down the Bear River Valley and used, first at a point in the Bear River gorge, where the initial installation will be 53,600 horse-power capacity, and, after that, at five separate points down stream, the most southerly being in the Auburn canyon near the town of that name in Placer County.

These additions to the Pacific Gas and Electric Company's equipment are costing several millions of dollars. It is expected that the first supply of "juice" from this new quarter will be available before the close of the present year.

The Pacific Gas and Electric Company has 3,895 miles of electric transmission lines of which, approximately, 1,500 miles are of high voltage, 60,000. The new plant is to have 118 miles at 115,000 volts. The main lines run down through the Sacramento Valley and cross San Francisco Bay at the Straits of Carquinez, between Benicia and Port Costa, to a sub-station on the hills back of Oakland, while another line reaches San Francisco and the peninsula from Electra, crossing the bay at a point near San Jose.

Next in importance to this great system is that of the Great Western Power Company, which harnesses the waters of the Feather River for its energy. To locate this we have to travel back to Butte County where, at a point a few miles north of Oroville, stands the Las Plumas power-house. This has a scenic advantage in that it is on the main line of the Western Pacific, and travelers overland that way are permitted a full view of the power-house across the river, with the water gushing from the tail-race. The water is diverted at Big Bar, eighteen miles upstream, but the river pursues so crooked a course that the tunnel conveying the water across country to the point where it is shot through the penstocks to the power-house is but three miles in length. This system is operated at a static head of 420 feet and has a present installed capacity of 53,600 horse-power.

The Great Western Power Company was incorporated in September, 1906, as successor of the Golden State Power Company, the Western Power

Company and the Eureka Mining Company. It operates its main transmission lines at 100,000 volts. These lines terminate at Oakland, and from this point a cable at 11,000 volts conducts a portion of the "juice," approximately 5,000 horsepower, across San Francisco Bay.

In the district around Oroville also operates the Oro Electric Corporation, a comparatively small undertaking so far as its present scope is concerned, but one which is seeking to branch out through the valley counties. This system includes two water-power plants located on the west branch of the Feather River, near Oroville, whose generating capacity aggregates 4,000 horse-power.

Running southward down the eastern border of the State as far as El Dorado County we reach the properties of the Western States Gas and Electric Company, successor to the American River Power Company which was formed in 1902. This organization operates a power-plant at the junction of Rock Creek on the South Fork of the American River, 7 miles north of Placerville, where the installation is of 4,000 horse-power. The transmission lines from this run to Stockton, where is located the head office of the Western States Company, which owns the distributing system in and around Stockton. The Company is helped out in its enterprise by the purchase of power from the Pacific Gas and Electric, Great Western Power, and the Sierra and San Francisco companies.

Mention has already been made above of the plant which this company, which is owned by the Byllesby Company of Chicago, operates in Trinity County.

Pursuing our southward journey as far as Tuolumne County we reach the water-power source of the Sierra and San Francisco Power Company, an organization which is owned by the interests that control the United Railroads of San Francisco, and which supplies power for the operation of that street-railroad system. The main water-power plant is situated on the Middle Fork of the Stanislaus River, about 14 miles from the historical Angel's Camp, of which Bret Harte has written so much. The installation here is in the neighborhood of 35,000 horse-power. There is another power-plant on the South Fork of the same river of 2,000 horsepower capacity and a third one, very much smaller, at Knight's Ferry, near Oakdale, in San Joaquin County.

This company's development dates from 1906, and the first line was built into San Francisco in 1910. The main transmission lines cross the Bay at Dumbarton Point and run to the company's Bay Shore station in San Mateo County. The company has a sub-station in the San Joaquin Valley whence electric "juice" is supplied to all the towns lying between Stockton and Modesto. Another branch of its distributing system furnishes power from a sub-station at Alviso to the Santa Clara and Salinas valleys. The company has 275 miles of double construction steel towers across country; 100 miles of double line to San Francisco Bay and a single line into San Francisco from the San Mateo sub-station. There are thirty miles of single line from the Santa Clara Valley.

The next system of consequence reached in our southward journey is that of the San Joaquin Light and Power Company, the northern section of an enterprise which covers practically all the territory from Merced down to the southern border of the State. The lower connecting link is supplied by the Pacific Light and Power Company, which is operated by the same interests that control the San Joaquin Company. However, they are operated as separate companies and for the purposes of this article may be treated as such.

The first San Joaquin plant was built in 1911, replacing an old one constructed five years previous. It is located on the North bank of the San Joaquin, about 36 miles northeast of Fresno. The installation here is of about 17,350 horse-power. The water for this plant comes through the Crane Valley reservoir, a branch of the North Fork of the San Joaquin. Before it reaches the big plant it passes through a smaller one where there is an installed capacity of 4,000 horse-power. There is a third plant now under construction. It is located between the two others mentioned and will have a capacity of about 4,000 horse-power. The company also has a plant at the mouth of the Kern River canyon about 10 miles east of Bakersfield. This is one of the earlier California plants and was built in 1897 and 1898. Its installed capacity at present is 2,000 horse-power, but that is to be replaced by a more modern installation of more than double the capacity. There are two main lines running from the power-plant, one on the east side and one on the west side of the San Joaquin Valley to Bakersfield, and a line running from Fresno to the coast of San Luis Obispo and the surrounding country. The California oil fields furnish a considerable portion of this company's income.

Right here in Fresno County we strike the trail of the connecting link referred to, namely, the Pacific Light and Power Company's developments. With the assistance of the Stone and Webster Construction Company this organization is at work on two large hydro-electric plants on Big Creek, a tributary of the San Joaquin River and at a high altitude in the Sierra Nevada Mountains, about 60 miles northeast of Fresno. The second plant will take the water from the discharge of the first one. The total amount of power generated will be about 100,000 horse-power. A large reservoir at the upper end of this system will supply sufficient water during the low period, and the water will be carried to both plants through tunnels and pipes.

For construction purposes a railroad has been built to the site of these plants from Polaskey, the terminus of a branch of the Southern Pacific, a distance of over 40 miles. The magnitude of this undertaking can be appreciated from the fact that it is proposed to conduct power from the big plants directly to the City of Los Angeles, a distance of about 250 miles. The voltage of this transmission will probably be 150,000.

The Pacific Light and Power Company's territory takes in all the districts south of Tehachapi, including Los Angeles. At the present time it has four hydro-electric generating stations in operation. Of these the largest is the Borel plant on Kern River about 30 miles east of Bakersfield, where the installation is of 13,400 horse-power; but it is of record that this plant has never been able to operate at its full capacity. There is a double transmission line from Borel to Los Angeles, 110 miles. Near Azusa, about 30 miles due east of Los Angeles on the San Gabriel River, is another plant of the company's earliest hydro-electric development. It is a comparatively small installation of 1,600 horsepower. A third plant, situated in Santa Ana canyon directly north of San Bernardino, supplies about 1,500 horse-power.

Over in Tulare County is found the system owned and operated by the Mt. Whitney Light and Power Company, whose headquarters are at Visalia. This company has three power plants, two on the Kaweah River and the other on the Tule River. They are comparatively small installations.

Running to Los Angeles, we find another corporation operating there, the Southern California Edison Company, a successor to the West Side Lighting Company, the Redlands Electric Light and Power Company, and the Edison Electric Company. It was originally built to carry power from Redlands District to Los Angeles. This company has no less than seven water-power plants in operation at the present time, one on Kern River, three on Mill Creek, two on the Santa Ana River and one on Lytle Creek. That on Kern River is the only large one, having an installed capacity of 26,800 horse-power. The Mill Creek plant is of 4,000 horse-power, and there is an installation of a similar capacity at one of the Santa Ana River plants. The other plants are very small. The Southern California Edison Company operates over a territory taking in Orange, Kern, Ventura and San Bernardino Counties, and a slice of Riverside.

Two other companies might be mentioned, the South Sierras Power Company and the Truckee River General Electric Company. The first is a successor of the old Nevada-California Power Company, whose development is located on Bishop Creek, a tributary of the Owens River, where are three water-power plants of an aggregate generating capacity of 18,000 horse-power. But this company, while having its headquarters at Los Angeles, disposes of its output in the adjoining State of Nevada for the main purpose of operating the mines there. However, it is planning to bring its transmission lines into San Bernardino where it operates a steam plant.

The Truckee River Company claims acquaintance with California for the reason that Lake Tahoe is its reservoir. However, this is used only on the Nevada side and the power is all distributed in that State.

This article has touched the high spots only of hydro-electric development in California. Nothing has been said about steam plants, though it is understood that most of the big companies reinforce their water-power development by this means in the big cities. The present total installation of steam plants for light and power purposes aggregates, approximately, 200,000 horse-power. It is safe to say, however, that as matters are at present, there is no likelihood of steam ever displacing water-power for general commercial purposes.

So, as long as the snows shall gather on the summits of California's high mountains so long shall men penetrate the mountain fastnesses and compel the waters of the streams to do their will. It is all in the line of progress and development, and by means of the great storage reservoirs and irrigating systems which form part of many of the big power companies' developments, comfort and prosperity are offered to the farmers and the residents generally in many sections of the State that under ordinary circumstances would be crying for water during a considerable portion of the year, due to the climatic condition of a long summer period of absence of rainfall. This period generally extends from absence of rainfall. This period generally extends from April to October, when the fruit, alfalfa and grain lands are dependent upon stored waters for irrigation after the natural flow of the streams has subsided.

The hydro-electric companies, therefore, are benefactors in this respect and are conservationists in the most liberal and generally accepted interpretation of the term.

The Principles of Fuel Oil Engines—III*

The Chemical and Physical Basis of Their Operation

By C. F. Hirshfeld

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IT is a matter of practical experience that the use of water in kerosene and other oil engines materially improves operating conditions. The explanations which have been offered are numerous and varied and there is probably truth in most of them. There are, however, some which have not yet been suggested so far as my knowledge goes. We will consider all of them, new and old, very briefly in such a way as to bring out the essential points. They are:

1. The use of water serves to maintain low temperature during compression and thus prevents cracking. This is due to the absorption of heat during vaporization and subsequent superheating of the water vapor. It should be noted that such cooling will materially retard the rather difficult vaporization of the fuel.

For maximum cooling effect the water should be introduced as finely divided liquid spray at the beginning of the compression stroke or earlier; for minimum cooling it should be introduced in the form of superheated vapor as late as possible in the compression stroke. The best conditions will vary with fuel, engine, and load. Observe that if the conditions of water injection (quantity, condition and time) remain constant from no load to full load they can be correct for one load only and must be more or less wrong for all other loads. Suppose, for instance, that the water is regulated properly for full load. At lighter loads the cooling effect will be too great; vaporization of the fuel will be retarded, condensation on cold walls will become excessive, and low temperature and pressure will cause slow flame propagation of pressure during combustion.

* Paper read before the American Society of Agricultural Engineers and published in the *Gas Review*.

2. The use of water probably leads to a water gas reaction with the hydrocarbons or with some of the carbon liberated from those hydrocarbons, resulting in the formation of CO_2, CO, and H_2. This would prevent the deposition of some carbon which would not otherwise be burned and would therefore result in a cleaner engine. These water gas reactions start at a temperature of about 1,000 deg. Fahr. and are very active at a temperature of 1,800 degrees; they cannot, therefore, occur to any extent during compression as has been assumed by some.

A very common error in this connection is to assume that the hydrogen of hydrocarbons burns first and leaves the carbon behind, and that the deposition of carbon is due to the great difficulty of making the oxygen combine with this carbon. So far as experiment has gone, it shows that carbon burns first and that it forms CO. The hydrogen then burns with such oxygen as is left in the neighborhood unless the temperature is so high that it cannot combine with oxygen, that is unless the temperature is above the dissociation temperature of water. The carbon deposit with which we are so familiar must therefore be formed by the cracking of hydrocarbons which have not yet started combustion, much as was explained in previous paragraphs. This all indicates that fine spraying, which will result in a uniform distribution of combustion, will tend to prevent the formation of carbon.

3. It has been suggested that the presence of water or of superheated steam prevents the cracking of hydrocarbons because of some unknown chemical action. So far as has yet been shown this is not correct. The argument is based upon the fact that the oil refiners use superheated steam to prevent cracking during distillation, but the action in this case is purely mechanical; the steam carries the vapors out of the heated zone in which cracking would ensue. Obviously we need not further consider this case.

4. The presence of water is supposed to prevent excessive rise of pressure during combustion by dissociating and absorbing heat. This is probably true to a certain extent, but the amount of dissociation of the kind ordinarily meant is probably small and its effect of corresponding magnitude. The principal effect of the water at this part of the cycle is probably due to the following four phenomena.

5. As cracking continues during combustion in the way already explained, the water gas reactions which all absorb heat probably continue and thus keep down temperature and pressure.

6. The water vapor has a relatively high specific heat and since its temperature must be raised with that of the surrounding gases, this tends to keep the ultimate temperature and pressure low.

7. The water serves as a diluent of the combustible mixture just as any other gas or vapor would and it thus decreases the ultimate maximum pressure. Its action in this way would be particularly noticeable at the higher loads when the velocity of flame propagation in the undiluted mixture would reach its maximum value.

8. The water vapor is the same chemically as one of the products of combustion and hence increases the concentration of the mixture with respect to this constituent. But the chemists have shown that in reactions of this kind the velocity of the reaction is determined by the concentration; it is greatest when the concentration of one of the resultants is least and it decreases as the concentration with respect to that resultant increases. Thus the presence of water vapor retards the formation of more water vapor by combustion and thus retards the rate of combustion, which in turn means a lower final temperature and pressure.

Other possible actions of water vapor which would have a beneficial effect, and which probably occur, are the following:

9. The water must vaporize very rapidly during the compression stroke since its vapor pressure will be high at the temperatures attained during this part of the cycle. In vaporizing rapidly and diffusing through the mixture it must cause considerable commotion and thus churn up the other constituents and assist the diffusion of the hydrocarbon vapors which are more sluggish.

10. It seems probable that the small particles of carbon which are cracked out of the hydrocarbon vapors adsorb water vapor to a certain extent and are thus prevented from agglomerating so that they remain small and light enough to float instead of becoming large, heavy particles which will collect on the walls or pass out with the exhaust as visible smoke. Such suspension would naturally assist in promoting combustion because the small particles would remain floating in the midst of a hot turbulent mass of gas containing oxygen instead of collecting on the relatively cool walls.

From this collection of the probable activities of water in the engine cylinder it is evident that the behavior of water under these circumstances is very complicated and that no single explanation of such action is possible.

It will also be evident that within limits the action of the water will be dependent upon its quantity. Too little will give all the troubles with which the engineer is familiar; too much will cause similar troubles. The proper quantity in any engine varies with the load, though not in direct proportion. In every engine so far constructed the quantity which is correct for full load is far from correct for light loads, and will, in general, cause the deposition of considerable soot and give a smoky exhaust. It is also true that the correct quantity will vary with the size of the engine, the proportions of the cylinder and clearance space, the degree of compression, the speed, the average temperature maintained in the various metallic parts, and the method and time of introducing the fuel. Each engine and each size of engine therefore presents its own individual problem and the solution must be determined experimentally.

We may conclude in a general way that in the case of small engines it will be possible to obtain fairly satisfactory results without the use of water if we maintain a fairly high wall temperature, do not use too high a compression pressure, and introduce the fuel in a very fine spray during the suction stroke or near the beginning of the compression stroke. It will be necessary to clean the engine periodically, but this is not a great commercial drawback in small sizes. The use of water adjusted to give best results for from half to three quarters load will probably improve conditions somewhat and allow cleaning at longer intervals.

The regulation of the water so that it varies with, but not as, the load will give still better results and will permit of higher compression.

The use of water in this way can be made to give almost perfect results with kerosene, but even this arrangement falls short of all that is desirable with the heavier and cheaper fuels. The reason is obvious, but it should be noticed that very fine spraying of the fuel will counteract increased density and viscosity to a very great extent in any type of engine.

Thus far we have confined our attention to the external preparation of fuels by means analogous to those used with gasoline. There is, however, another distinctly different means employed which may be called the retort process. The fuel, or the fuel and some or all of the air, with or without water, are passed through a retort or pipe heated by means of the exhaust gases. The products of distillation and cracking or these combined with the products of reactions between water and carbon are then carried into the engine cylinder for combustion. This method is capable of giving very satisfactory results with kerosene, particularly when water is used and when the load is fairly steady, but when heavier fuels are used it generally leads to trouble by the formation of excessive quantities of carbon and pitch. These collect in both the cylinder and the retort. The most prominent difficulty is that of temperature control; the retort temperature which is correct for full load is far from correct for fractional loads. Therefore, with decreasing loads there is a tendency toward excessive cracking, while with increasing loads the vaporization of the fuel is incomplete. Either effect will, of course, give trouble.

Another source of trouble is the condensation of fuel within the cylinder. The retort prepares a mixture of fixed gases and vaporized liquids at a comparatively high temperature and some of these vapors have a tendency to condense on the cooler cylinder walls.

There is one property of hydrocarbons which should be of great importance in connection with the retort method, but it seems to have gone unnoticed up to the present time. Hydrocarbon liquids can be maintained at high temperatures for long periods of time without any appreciable cracking if the vapors which distill off are not allowed to remain in contact with hot surfaces. The heaviest hydrocarbon liquids can also be entirely vaporized at very low temperatures by bubbling air through them. Thus solid paraffines which melt at temperatures in the neighborhood of the boiling point of water can be entirely vaporized without cracking if they are melted, maintained at such a temperature that they are limpid liquids, and have air bubbled through them. The liquid will entirely disappear and no carbon or pitch will remain behind. This method looks very promising from a theoretical view point and warrants investigation.

Since external retorts are found to lead to difficulties of the kinds mentioned, the next logical step is to place the retort in such a position that it will be least subject to the things which cause these difficulties. This leads to the combination of the retort with the cylinder giving the familiar hot bulb or hot head type of engine. Such constructions do not entirely eliminate the difficulties previously spoken of, but they can be made to partly do so.

They vary all the way from the original Hornsby-Akroyd type in which practically all the fuel vaporization, mixing and ignition occur within the hot bulb to the De la Vergne Type F. H., in which the function of the bulb is pre-eminently that of an ignition device, and very little that of a vaporizer.

With low compression pressure and without water injection, the forms in which fuel is sprayed into the interior of the bulb at such a time that vaporization and cracking are almost complete before the entrance of any appreciable quantity of air to the bulb are fairly satisfactory. They can be used with very heavy fuels, but there is naturally a collection of carbon in the bulb and more or less of this is always carried into the cylinder. Periodic cleaning of the retort is therefore necessary and the cylinder and valves will also require cleaning occasionally.

Engines of this type are difficult to keep in best working adjustment, and when operating imperfectly there is a rapid and cumulative collection of carbon and pitch which continuously tends to make matters worse. The boundary region between perfect and imperfect operation is very narrow and the engine must be operated in this region. The difficulties come largely from inability to maintain the same bulb temperature from day to day and the impossibility of regulating this temperature to suit the load being carried at the time. There is also the difficulty of obtaining a good mixture as this has to be made in a short time and is largely dependent on natural diffusion.

When water is used, more liberties can be taken with the vaporizing process. Thus the fuel can be injected into the clearance space during suction or compression, the direction of the jet being such as to bring it against a heated projecting lip or something of the sort. Means may be introduced to mechanically assist mixing since the presence of water makes it unnecessary to keep vapors and air separated to prevent early ignition. It is also possible to carry a higher compression without danger of preignition for reasons which have already been explained.

As in previous cases, the finer the spraying of the fuel the better the operation, provided the water is properly regulated. The simplest way of looking at this part of the problem is the following. The fuel is to be sprayed as fine as is commercially possible in the type of engine to be constructed. In this way the vaporization will be made as perfect as possible. Water will be used in such proportion as to prevent the early ignition of the vapors formed, but not in sufficient quantity to cool to a greater extent.

This matter of fine spraying is of the greatest importance and does not seem to have been fully appreciated by many of the engine builders. A number of otherwise perfect engines have failed because of this simple imperfection, the author having very vivid recollections of the wild speculations which were indulged in at the time in vain attempts to explain the trouble.

It is obvious that if we are to utilize the heavier fuels we must use heat in some way so as to assist in vaporization and mixing. The retort has been found to be subject to certain imperfections which are inherent in the retort method. These imperfections are largely due to inability to keep temperatures where we want them and to prevent cracking of vapors in contact with the hot walls of the retort. If we could devise a means of maintaining a very high temperature at all times, irrespective of the load, we could vaporize the fuel in a very short time if we sprayed it fine enough. If we further did not inject it into the engine until we desired combustion there would be no necessity of keeping the hot vapors out of contact with the air and we could use any means available for producing perfect mixture.

Observe that these things are just what are done in the Diesel engine, which is really an example of the interior retort type, the hot surfaces being replaced by hot gases which owe their high temperature to the previous compression by the engine piston. The fuel must be sprayed very fine so that vaporization is practically instantaneous, and it must be very forcibly injected so as to produce perfect mixture in the short time available.

It must be admitted that from the theoretical standpoint the Diesel type is the most perfect for the utilization of the heavier liquid fuels. Practical experience also shows that it is the most perfect. It is, however, very seriously handicapped by high pressures which call for great strength and weight and by very delicate mechanism which calls for fine workmanship and a high class of attendance. As a result, the Diesel engine is not available for agricultural and similar purposes and we must make up our minds that we must find methods which may not be as perfect, but which will be more commercially applicable. It is hoped that the various things pointed out in this paper may enable those interested to arrive at a clearer understanding of the problem, which after all, is the first step in its solution.

Some Defects Inherent in Photographic Views*

False Perspective of Photographs As Ordinarily Prepared

By Dr. A. Gleichen

We saw on a former occasion that the camera is in this respect an imperfect imitation of the human eye, that it corresponds at best to a single eye, while the normal man has a pair of eyes. This defect can, of course, be remedied by the use of a spectroscopic camera, but the great bulk

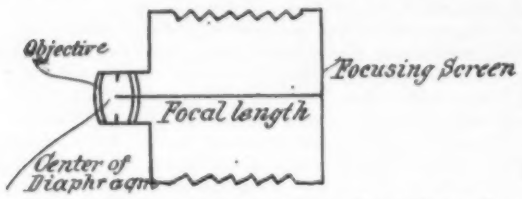


Fig. 1.—Diagram showing the essential features of a photographic camera.

of pictures are taken with the ordinary camera, and it is of pictures so obtained that I wish to speak here.

A picture taken with a single camera has of course one specific perspective, namely, that which the landscape would present to an eye located at the same point as the lens of the camera. An eye which views the photograph *from the proper point of view* has exactly the same perspective view of the landscape as if it viewed the latter directly. The phrase *from the proper point of view* requires some explanation. To make it clear we shall have to make a slight digression.

The modern photographic objective is usually composed of a number of lenses, somewhere among which is placed the so-called diaphragm. This serves to adjust the effective aperture of the lens according to requirements. According to the position of the diaphragm relatively to the lenses we distinguish symmetrical and unsymmetrical objectives. An interesting case of the latter type is the telephoto objective, which consists essentially of two lenses, as shown in Fig. 2. This combination has the property of forming comparatively large images of distant objects, and is particularly well adapted for taking photographs of inaccessible objects.

If a photographic objective is screwed from its socket and is held out at arm's length against a bright background, it presents to the eye a luminous disk, which is known as the entrance aperture. If the objective is turned about, so that now one is looking in through the face normally turned toward the focusing screen, a similar luminous disk is seen, which is known as the exit aperture. In the case of symmetrical objectives the two apertures are equal, in unsymmetrical objectives this is not the case. Thus, for example, Fig. 3 shows the entrance and exit apertures of a telephoto lens, which, as will be seen, are quite different in size.

We are now in a position to define precisely the term *the proper point of view*, which was used above in speaking of the perspective of a photograph.

In the case of a photograph taken with a symmetrical objective, the proper point of view from which to regard the photograph lies at the same distance from this photograph as the plate or film lay from exit aperture when the photograph was taken.

If the camera is focused upon distant objects, this *proper point of view* is practically one focal length distant from the picture.

In the case of unsymmetrical objectives a correction has to be applied by multiplying the distance determined as above by the ratio of the diameter of the entrance aperture to that of the exit aperture.

The landscape shown in Fig. 4 was taken at a focal distance of seven inches. It should therefore be viewed from a distance of seven inches. If it is thus viewed *with*

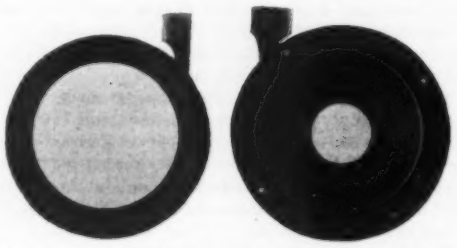


Fig. 3.—Front and back apertures of telephoto lens.

one eye, the perspective is the same as if the landscape had been viewed directly from the point at which the lens was situated when the picture was taken.

Now most persons who have reached a certain age, and who are not shortsighted, can not obtain a clear view of a picture at such short range. They can, however, find a way out of the difficulty by making themselves, as it were, artificially shortsighted, i. e., by interposing a convex lens of about seven inches focus between the photograph and their eye. They can then in comfort view the photograph at a distance of seven inches. It is not, of course, necessary to observe accuracy within a fraction of an inch.

Now as a matter of fact the majority of cameras used by amateurs have a focus of only about 5 to 6 inches, so that for most persons it is quite impossible to obtain the correct perspective by simply looking at a photograph obtained with such a camera, even if one looks with one eye only. As a matter of fact such photographs are frequently hung on the wall, and looked at from an utterly inappropriate point of view. Added to this is the fact that they are looked at with both eyes, so that the fact of the picture being in one plane is irresistibly forced

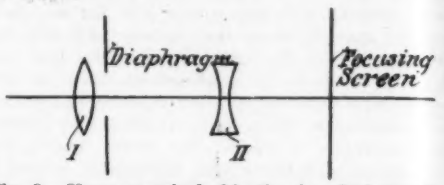


Fig. 2.—Unsymmetrical objective in which the diaphragm is not midway between the two lenses.

upon one's observation, thus spoiling any possible remnant of the perspective.

The question arises, what can be done to avoid these defects of the customary type of photographs?

The first thing that occurs is to use a long focus lens, say of 10 to 12 inches. Then we have at least the right perspective for one-eyed vision.

To get rid of the effect of stereoscopic vision forcing upon the observer the fact that he looks at a plane object, we may take advantage of the fact that the stereoscopic depth-effect diminishes very rapidly as the distance from the object increases. At a distance of some 24 to 28 inches it is practically *nil*. In order, therefore, to obtain a satisfactory effect, we should have to employ a camera of at least 24- to 28-inch focus. This is, of course, out of the question for the average amateur. True, somewhat more satisfactory results could be obtained by the use of a telephoto lens. But this type of objective is not very well adapted for general work.

There is, however, another method of obtaining the requisite distance for the point of observation, namely, by enlarging the original. If, for example, a view taken with an 8-inch focus is enlarged to four times its original size, then the proper point of view is 32 inches from the photograph, and in these circumstances the disturbing effect of two-eyed vision is practically eliminated.

The very excellent perspective effect of moving pictures is largely due to the fact that they are greatly enlarged, and looked at from a considerable distance.

* The article here translated from *Prometheus* should be read in conjunction with the same author's article "The Human Eye and the Photographic Camera," in the last issue of the Scientific American Supplement, page 51.

Fig. 4.—To see this picture in its true perspective, it must be viewed at seven inches from the eye, which for a person with normal vision is too near for clear perception. By the aid of a magnifying glass, however, it is possible to approach within this distance and still obtain a clear view.

Cold Storage Temperatures

The following cold-storage temperatures for different classes of goods were given by the Committee on Refrigeration of the National Electric Light Association:

	Deg. Fahr.	Specific Gravity.
Beef (fresh)	36–40	0.68
Hogs	29–32	0.51
Lamb and mutton	32–36	0.67
Veal	34–36	0.70
Meats (in pickle or brine)	35–40	0.54–0.58
Butter	0–38	0.64
Eggs	29–32	0.76
Cheese	32–34	0.64
Lard	38–40	....
Poultry (to freeze)	5–10	0.78
Poultry (when frozen)	25–28	....
Game (to freeze)	5–10	0.80
Game (when frozen)	25–28	....
Fish	25–28	0.82
Oysters	33–45	0.84
Beer	33–42	0.90
Wines	40–45	0.90
Cider	30–40	0.90
Fruits	33–36	0.92
Vegetables	34–40	0.91
Canned goods	38–40	....
Flour and meal	40	....
Furs	25–32	....
Brine for ice cream freezing	5–10	....
Ice cream (air hardening)	5	....
Ice cream (serving temperature)	14–16	....

Mechanical refrigeration as applied to cooling water and milk usually has one feature different from other classes of refrigerating work. A large quantity of cooling effect is called for in a brief interval of time. For instance, in a drinking-water system the heaviest requirements may come at the noon hour. In dairy work the milk must be cooled rapidly to check the development of bacteria.—*Power.*

The Physical Basis of Life

Laboratory Models of Living Organisms

WHAT is life? A question frequently asked, perhaps an idle question. However that may be, the investigation of the relation of life phenomena to the general laws of nature is very far from being an idle pursuit, in fact it might be said to be the chief task of science, inasmuch as all human endeavor has its root in the instinct of the preservation of life.

Until fairly recently there was something of a chasm between the worker in the so-called "exact" science of physics and the biologist. To the physicist the test of perfection in scientific work is mathematical precision. The biologist of the old school usually abhors mathematics. But these things are changing. Mathematics has invaded biology, and the mechanistic conception of life, no longer a mere subject for philosophical debate, is receiving experimental support—it would be premature to say demonstration—by concrete experiment. The work of Prof. Leduc, of the University of Nantes, will always remain valuable, even if it should ultimately be found that its bearing upon the "riddle of life" is not as immediate as its author supposes. But it must be said that his observations have much convincing power.

Prof. Leduc, writing in *Kosmos*, points out that the typical life unit, the cell, is a "center of forces," around which radiate inwardly assimilative forces, carrying in food material, and outwardly excretory forces, carrying out waste matter. He set himself the task of constructing a purely physical system having similar properties, and succeeded by a very simple expedient. A layer of a solution of saltpeter is spread out over a horizontal glass slide, and into this a drop of India ink is allowed to fall. It spreads out in radial streaks as shown in Fig. 1, and the structure so formed possesses many remarkable properties, in which it resembles certain living organisms. Thus it might be said to possess a sense of touch, for when a glass rod is brought into the drop, the streams of pigment close in toward it like lines of force. If the rod is made of paraffin, on the other hand, the stream lines diverge, as if they were trying to avoid contact with this body (Fig. 4). These are what the physicist calls surface tension effects.

But the ink stain resembles certain organisms not only in its reaction to such mechanical stimuli as just described. The analogy goes further. When malic acid is allowed to diffuse slowly from a glass tube into water harboring the mobile sperm cells of certain forms, these immediately move toward the point from which the acid proceeds. It is as if they had a special liking for malic acid. Other substances on the contrary are shunned by these cells. This phenomenon is technically known as chemotaxis or chemotropism.

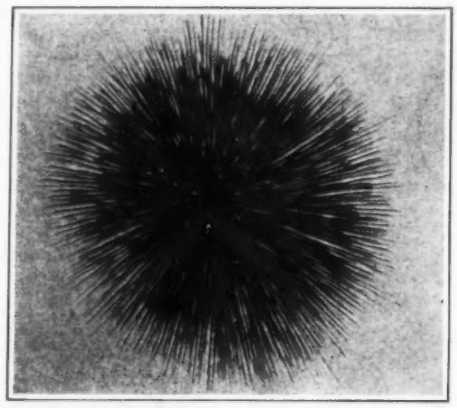
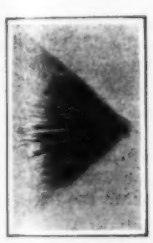


Fig. 1.—Photograph of a drop of liquid stained with India ink, shown in the process of diffusion.



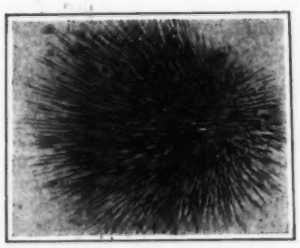


Fig. 2.—A cone of India ink converging toward a crystal of saltpeter. Fig. 3.—Ink stain receding from light and into shade.

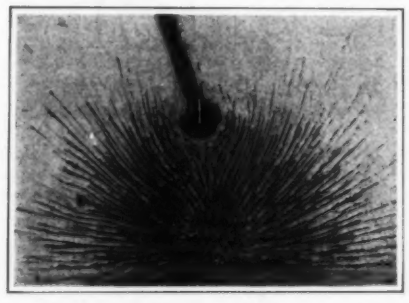


Fig. 4.—Reaction of stain to the approach of a paraffine rod. The ink draws away from the rod owing to the effect of surface tension.

Now our ink stain possesses quite unmistakably this property of chemotropism. If we introduce into a dilute solution of saltpeter a crystal of saltpeter, and at a little distance from it we drop our ink stain, the particles of carbon of the Indian ink flow in toward the crystal, as clearly shown in Fig. 2. The point of the cone there seen is the crystal of saltpeter.

An experiment of peculiar interest, in view of its bearing on the phenomena of smell, is shown in Fig. 5. In this illustration is seen on the right a glass rod ending in a knob. This rod has been wetted with absolute alcohol, and brought within a little less than an inch of the liquid containing the ink stain. The vapor of the alcohol reaches the liquid and affects the streamers of the ink stain in the manner shown: they turn away from it, giving it a wide berth. It seems not improbable that our sense of smell depends on some such action as this.

As our readers know, many forms of life are sensitive to light, which they either seek or shun. This may by some be ascribed to voluntary action, or at any rate to some specific vital phenomenon.

But our ink stain shows precisely similar heliotropism, as this phenomenon is called. In Fig. 6 the ink stain is seen streaming away from the right to the left-hand portion of the field: away from the light to the dark portion, as the experiment was arranged.

Another "tropism" characteristic of certain living organisms is galvanotropism, the faculty of following the lines of flow of an electric current. That the ink stain possesses galvanotropic properties is shown in Fig. 6.

The field opened by Prof. Leduc is of peculiar interest and promises to bring us important disclosures regarding some fundamental life phenomena. We must in patience await further developments.

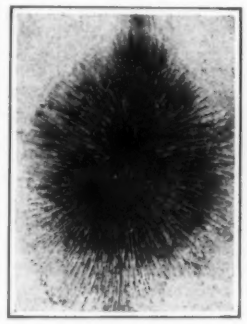


Fig. 5.—Action of alcohol vapors upon India ink stain. Fig. 6.—Action of the electric current upon carbon particles of India ink stains.

Heredity and Microscopic Research*

Structural Features Which Accord With the Laws of Mendelian Inheritance

By Prof. E. B. Wilson

MORE than half a century has passed since Leidy's earliest studies with the microscope. The main motive power behind the unparalleled advance in biology during this period has been the persistent effort to explain the activities of living things through investigations upon their structure, whether anatomical, physical or chemical. This effort entered upon a new era with the discovery of protoplasm and the promulgation of the cell-theory; for its final objective was now seen to lie in minute structural elements, the cells, of which the tissues are composed. Little by little it became clear that the cell, whatever else it be, is a microscopic chemical engine, where the energy of the foodstuffs is finally set free, and applied to the work of life. The question inevitably arose whether we can discover within the cell any visible apparatus by which this is accomplished. The inquiry has a thousand aspects; I ask your attention to that which relates to the problem of heredity.

It long since became clear that the cell-theory offers us a general explanation of heredity. Heredity is a consequence of the genetic continuity of cells by division, and the germ-cells form the vehicle of transmission from one generation to another. This fundamental discovery divested heredity of the mystery in which it had so long been enveloped, though it must always remain among the most wonderful of phenomena. But this result only cleared the way for further advances. Our scientific curiosity is aroused in the highest degree by more specific problems of heredity. Why do individuals now and then appear that show little resemblance to their immediate progenitors but "revert" to much more remote ancestors? Why do the grandparents often exert definite effects upon their grandchildren of which no suggestion is given by their children? What explanation can be offered of the combinations and recombinations of parental or grandparental characters that appear in definite numerical proportions in hybrids? We may glance at a few particular cases that will serve to place some of these questions before you in more concrete form. Let us first of all consider the results of crossing two distinct races of sweet peas, each of which is pure white and produces only white offspring so long as strictly inbred. On crossing the two races the hybrids are always deep purple, like the wild Sicilian species, and in this respect they no doubt revert to an early common purple ancestor of the two white races. The offspring of the hybrids include a variety of purple, red and white forms, among which are whites that are identical with the two original grandparents. A somewhat similar case occurs in domestic fowls. We may have two different white races, each of which breeds true; but when crossed together they produce deeply colored hybrids, showing a pattern of plumage that is closely similar to that of the wild jungle fowl from which both white races are probably descended. How is the reversion shown in this and the preceding case to be explained?

Let us look at some more complicated phenomena. Just consider the result of crossing two differently colored races of fowls, the barred Plymouth Rock and the black Langshan. If the barred cock be paired with the black hen, all the offspring are barred, like the father. If the barred hybrids be paired together the progeny includes, on the average, three barred to one black, and the black bird *is always a female*. Quite different, and even more singular, is the reverse cross where the black cock is paired with the barred hen. Half the offspring are now barred and half black; and the remarkable fact is that the barred birds are all males, the black ones all females. In color pattern the sons are like their mother, the daughters like their father, an example of the so-called "criss-cross" heredity. Upon pairing these

* Abridged from a lecture delivered before the University of Pennsylvania, April 17th, 1913, on the Joseph Leidy Foundation, and published in *Science*.

hybrids together, the following generation (grandchildren of the original forms) includes males and females of both types, barred and black.

Such results seem at first sight capricious, almost fantastic, but this first impression is erroneous. The results are not capricious, but constant. The experiments may be performed over and over again, always with the same result, so that the outcome may be unfailingly predicted in advance; and this demonstrates that such forms of heredity, and heredity in general, must be due to some definite apparatus in the germ-cells. I shall try to show that microscopical research has revealed to us at least something of the nature of this mechanism, and that it has practically solved some of the very puzzles that have

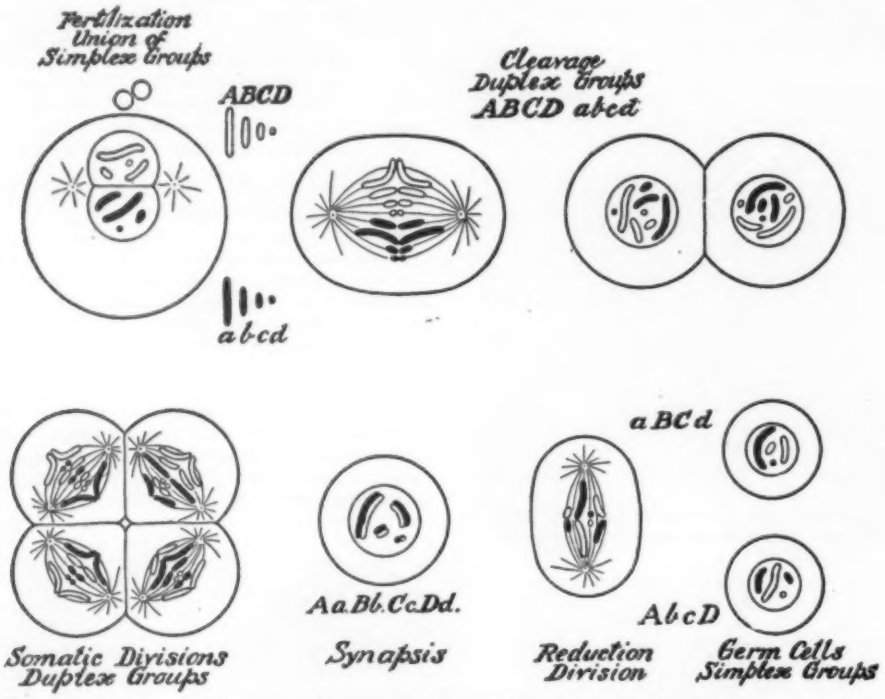


Fig. 1.—Diagrammatic representation of the process of cell division.

just been propounded. In order to indicate the nature of this solution, I must first ask attention for a moment to the so-called "unit-characters" and their behavior in heredity, on which the attention of both cytologists and experimenters on heredity has been largely concentrated in recent years.

Unit-characters have become too familiar to require more than brief illustration. Examples of them have just been seen in the colors of flowers or of plumage, and in the structure of the wings in flies. Their interest lies especially in the fact that they are transmitted independently of one another, as if they were separate and independent things. By appropriate crossing experiments, such as we have just seen, particular groups of such characters may be split up and recombined, over and over again, in constantly new combinations, with no alteration of their individual character. Let us look at one or two examples of this. Consider the results of crossing two different races of wheat (from experiments by Biffen.) One parent is a bearded variety with short, dense heads; the other a beardless form with long, loose heads. The hybrid is intermediate in shape, and is beardless. On pairing the hybrids together all combinations of the four original characters,

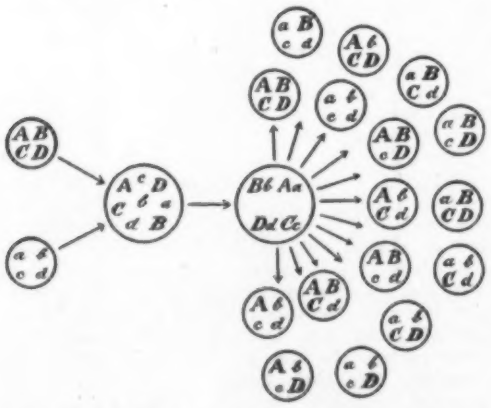


Fig. 2.—Diagram of inheritance of unit-character.

and of the hybrid character, appear in the grandchildren, namely, (1) short beardless, (2) short bearded, (3) hybrid bearded, (4) hybrid beardless, (5) long bearded and (6) long beardless. These six types appear in definite numerical ratios, and it is evident that the bearded or beardless character has been transmitted quite independently of the shape of the head.

Another and very striking case of the same kind is seen in Morgan's experiments on fruit-flies. The grandfather has white eyes and yellow body color; the grandmother, red eyes and gray body color. In the first generation all the offspring have red eyes and gray color. Among the grandchildren, however, appear not only both the original combinations but two new ones, namely, white-eyed grays and red-eyed yellows. Here again the second generation of hybrids shows all possible combinations of the four original unit-characters, white eye, red eye, yellow color and gray color. With a larger number of unit-characters the same would hold true, but the number of combinations would be much larger.

We catch a glimpse here of the methods by which the modern breeder of plants or animals is able to break up known combinations and recombine them into new types, somewhat as the organic chemist splits up known organic compounds and recombines the products into new compounds, perhaps unknown before. Our ability to do this is often of high practical value. As De Vries has said, most hybrids owe their character to a new combination of qualities. "It is the combination that is new," he says, "not the qualities themselves. Some characters are derived from one parent, others from the other. Each of these may be simply inherited, . . . but by their new combinations they yield varieties of higher practical value, and notable examples are afforded in those cases where one parent has contributed vigor of growth, hardiness in winter, resistance to disease or productivity, and the other bright flowers, palatable fruit or nutritive seeds." An example of this which he cites is Luther Burbank's celebrated white blackberry, produced synthetically by uniting in one race the light color of the fruit of an inferior variety of cultivated bramble with the large and succulent fruit of the Lawton blackberry. Another familiar example, also cited from Burbank's work, is the so-called Shasta daisy, which unites the desirable qualities of plants from three different continents. An English daisy has contributed its large flowers and tall, stiff stems; a Japanese species its whiteness of bloom; an American field daisy its profusion of flowers and hardiness in winter. Many other examples might be given to illustrate how by disassociation, recombination and selection desirable qualities may be brought together and undesirable ones eliminated; and by this principle the improvement of domestic races of plants and animals is being attempted in many parts of the world to-day.

Now, it is obvious that we should be able to understand the behavior of unit-characters, at least in some degree, if it could be shown that they are somehow dependent individually upon separate structural elements or different chemical substances that may be separately transmitted through the germ-cells. It is just this which microscopical research and experimental researches on heredity, taken together, have demonstrated. They have accomplished more than this. They have not only shown with a high degree of probability how the transmission of unit-characters is effected, but have thrown at least some light on the question how the splitting up and recombination of particular groups of such characters takes place. The main part played by microscopical research has been to bring forward proof that the hereditary characters are somehow connected with separate bodies, contained in or formed from the cell-nucleus, and known as the *chromosomes*. Besides the chromosomes the cell also contains another kind of bodies found in the cell-protoplasm, and known as *chondriosomes* or *plastosomes*. These, too, are very likely connected with heredity; but their true significance has not yet become very clear.

With the aid of the accompanying diagram (Fig. 1) we may consider a few essential facts concerning the chromosomes, leaving aside most of the complicated technical details. In each species of plant or animal the chromosomes are of constant, or nearly constant, number. They divide as the cell divides, and are thus transmitted from cell to cell. In the fertilization of the egg two similar groups of chromosomes are brought together, one contributed by the egg, one by the sperm-cell; and as the egg, step by step, divides to build up the body of the embryo the chromosomes also divide at each cell-division. Every cell-nucleus thus receives a double group of chromosomes, consisting of two single groups descended respectively from the two groups that originally came together in the fertilized egg. The two single groups of each nucleus are thus of maternal and of paternal ancestry, respectively. This all-important conclusion has been obstinately contested and is still denied by a few writers. I think, however, that all arguments against it must give way before the fact that in certain hybrids, in particular, certain fish-hybrids observed by Moenkhaus, the chromosomes of maternal ancestry can actually be distinguished by the eye from those of paternal. Finally, when new germ-cells are produced for the formation of the following generation the double chromosome-groups are again reduced to single ones in preparation for the succeeding process of fertilization.

These are not theories but observed facts. It is impossible to overlook the very precise parallel which they show to what Gregor Mendel and his successors have proved to be true also of the unit-characters, as will be made clear by the accompanying diagram (Fig. 2). When two similar or nearly similar individuals unite in fertilization they contribute to the germ two corresponding groups of unit-characters, which are designated in the diagram by two series of letters *A-D* and *a-d*, respectively. The offspring are therefore of double or "duplex" hereditary constitution. When the germ-cells are formed, as Mendel first proved by experiments on hybrids, they are found to carry only a single or "simplex" group of characters. So closely parallel is all this to what we have learned about the chromosomes that we can just as well use the diagram for the chromosomes as for the characters. Chromosomes and character alike form a single or simplex group in the germ-cells, a double or duplex group in the body of the offspring; and this alone is sufficient to make it extremely probable that chromosomes and

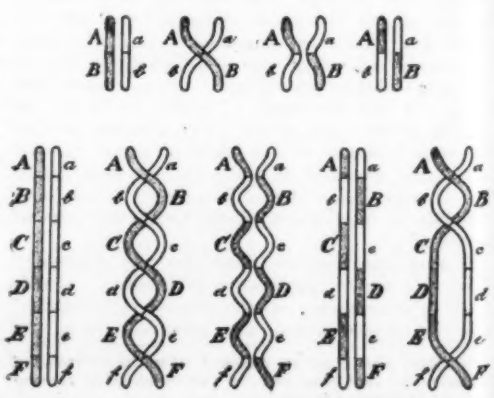


Fig. 3.—Intermingling of chromosome threads.

characters are somehow connected. Exactly what is the nature of this connection we are not able to say with certainty; but we might reasonably assume, for instance, that each character depends upon some particular chemical substance, or group of substances, contained in the chromosomes, and that different chromosomes differ in respect to the substances which they carry. Such an assumption would be thoroughly in accord with the principles of chemical physiology and with the results of experiments upon the physiology of development.

The diagram brings out another fundamentally important fact that was also proved by Mendel's experiments, namely, that in the formation of the simplex character-groups all possible recombinations of the original parental unit-characters (within the limits of a single complete group) are effected. Only a few of the germ-cells receive the original combinations unchanged (*A*-*D* or *a*-*d*). In most cases new simplex groups are formed by recombination, such that each germ-cell receives always a complete single series (from *A* or *a* to *D* or *d*), but any particular member of the series may be derived from either parent. The number of such possible combinations varies, of course, with the simplex number of unit-characters; with 4 characters, as in the present case, it is 16; with 15 characters it would be more than thirty thousand. Any individual may thus produce many different kinds of germ-cells, equivalent in a general way but differing slightly in respect to their individual hereditary components. This result follows from the fact, discovered by Mendel again, that corresponding or homologous parental components of the duplex groups (such as *A* and *a*, or *B* and *b*) never enter the same germ-cell; and this is the essential fact in "Mendel's Law." We could readily understand this if before the germ-cells are formed corresponding parental components become associated in pairs (*Aa*, *Bb*, etc.) and then separated or disjoined in an ensuing process of division. If the process of disjunction took place in each pair independently of the others, all combinations would obviously be produced in the resulting germ-cells. Now, it is certain that something like this actually takes place in the case of the chromosomes. In the process known as *synapsis*, which takes place shortly before the last two cell-divisions concerned in the formation of the germ-cells, the chromosomes do in fact unite in pairs, two by two. There is reason to believe that the two members of each pair are respectively of maternal and paternal derivation; and the probability of this view, first stated by Montgomery, has steadily increased. Observation has made it extremely probable that in the course of the following two divisions the two members of each pair, or two somethings that they contain, are separated so as to pass into different germ-cells (Fig. 1). One of the most interesting recent discoveries in cytology is the fact that in some animals and plants a paired arrangement of the chromosomes is assumed long before the period of synapsis, and may even be seen more or less distinctly throughout the life of the organism.

As has been said, the remarkable parallel between chromosomes and unit-characters constitutes in itself strong (though indirect) evidence that the latter depend in some way upon the former. Specific experimental evidence directly demonstrates the correctness of this conclusion. If, for instance, the orderly distribution of the chromosomes in the fertilized egg is artificially interfered with (as may be done in several ways) the development of the embryo is correspondingly disturbed. Boveri has proved that when abnormal combinations of the chromosomes are thus produced in the fertilized eggs of sea-urchins the offspring are almost always abnormal, deformed or monstrous. Recent experimental studies have proved by various methods that certain interesting abnormalities shown in hybrids are preceded by corresponding disturbances in the chromosomes. Again, it is now possible to fertilize the eggs of such animals as sea-urchins by the spermatozoa of animals as widely different as worms or mollusks. The offspring of such "heterogeneous" crosses show only the characters of the mother. They are typical sea-urchin larvæ; and the explanation, demonstrated by microscopical observation, is that only the chromosomes of the mother are able to survive in the fertilized egg. Those of the foreign father (i. e., of the sperm cell) sooner or later perish and degenerate within the egg.

Still another fact, of the same unmistakable import, is the recently demonstrated relation between the chromosomes and sex. Sex is now definitely known to be inherited like other characters; and within a few years the decisive proof has been attained that the heredity of sex is connected with a particular chromosome known as the "sex-chromosome" or "X-chromosome." In a large class of cases, to which man almost certainly belongs, the male contains but one of these chromosomes, the female two; hence, in such cases the total number of chromosomes in the female is one greater than in the male. In respect to these particular chromosomes, accordingly, the male always remains of simplex composition (XO), while the female is of duplex (XX). Observation has proved further than when the duplex chromosome-group of the female are reduced to simplex ones each mature egg retains a single X-chromosome, while in the male only half the spermatozoa receive X and half do not. From this it follows that when the egg (X) is fertilized by a sperm-cell containing X the result is a female (XX), while if fertilized by a sperm-cell without X, the result is a male (XO). I shall try to show a little later how clearly and simply these facts explain certain very curious special phenomena connected with the heredity of sex.

The specific and direct evidence thus briefly outlined has definitely established the fact that the chromosomes are causal agents in heredity; and it has already become evident that the study of their modes of distribution, combination and recombination provides us with a key which will unlock many special puzzles of heredity which would otherwise seem to us insoluble. I will attempt to make this clear in greater detail by considering three of the particular cases that have already been touched upon, taking them up in the order of their difficulty.

The simplest of these cases is that of reversion, illustrated by the sweet peas. It is evident from the experimental results that the purple color of the flowers requires the co-operation of at least two things, either of which alone is unable to produce any color. These two things may for the moment be called "A" and "B." Both A and B must obviously have been present in the original purple race from which the two white races are descended. One race has at some time in its past history lost A, the other B; and each loss has produced a specific type of white race which breeds true. By crossing the two A and B are again brought together, thus restoring the original combination AB; hence, the "reversion" to the purple wild type. Now, the things which we have called "A" and "B" may very well be different chemical substances. If we assume them to be borne by different chromosomes, brought together in the hybrid, the whole matter becomes at once clear and simple. It seems probable that all kinds of reversion may be explained by the same principle.

The second case is that of "criss-cross" heredity in the short- and long-winged flies, where the sons are like their mother, the daughters like their father. The explanation of this case is less easy to follow than that of reversion, but is more specific. This case, and many others of similar type, may be completely explained through our knowledge of the relation of the chromosomes to sex. These flies agree with the general rule already referred to, that the males contain a single X-chromosome, or sex-chromosome, the females two. All the facts revealed by experiment are very simply and completely accounted for by the single assumption that the X-chromosome is responsible not only for sex, but also for the short-winged character. Specifically, the assumption is that the short wings are due to the lack or defect of something (let us again say some definite chemical substance) that is contained in the X-chromosome. Let us see just how this works out. We may write the formula for the short-winged female as *xx* (the small letters indicating the defect in X that is responsible for defective wing development), while that of the normal (long-winged) male is XO. Such a female produces eggs of only one type, *x*, while the normal male produces sperms of the two types X and no X or O. Fertilization thus can only give rise to the two combinations *x*X and *x*O, the former being females, the latter males. The males are short-winged because they contain only the defective *x*. The females likewise contain such an *x*, but they are nevertheless long-winged because they also contain a normal X, which is sufficient to insure normal wing development. It follows that the daughters are long-winged like their father, the sons short-winged like their mother. I need not trace this explanation further into its details. It is enough to say that upon this one assumption the results of many other kinds of crosses among these flies work out perfectly; and a similar explanation will completely account for other cases of criss-cross fertilization, for such curious phenomena as the heredity of color-blindness in man, and many other cases in which particular somatic characters are linked with sex in a definite way. These cases offer, indeed, a brilliant example of the clearness and simplicity of the causal explanations that microscopical research has helped to give of complicated special phenomena of heredity.

As a third and last example I select an even more interesting and instructive case, the complete analysis of which carries us to the firing line of research in this field. It illustrates the influence of the grandparents upon the combinations of unit-characters seen in the grandchildren. It is a very curious fact, only recently discovered, that in certain cases hybrids of identical composition exhibit marked differences in their output of offspring that can only be explained by an exact knowledge of the grandparents. We have already seen a concrete example of this; but before returning to it the essential result may be explained as follows: Let us consider the case of a hybrid that contains four characters, which we will designate as *A*, *a*, *B* and *b*. The hybrid *AaBb* can be made in two ways, according to the composition of the parents. First, one parent may contribute *AB* and the other *ab*; or, secondly, one parent may contribute *Ab* and the other *aB*. These two crosses seem to give precisely the same result, *AaBb*. The hybrids produced by the two methods look exactly alike; they produce the same kind of offspring (grandchildren of the original forms). The remarkable fact is, however, that in some cases (probably in many) the offspring of the two kinds of hybrids differ in respect to the numerical proportions in which different combinations of the grandparental characters appear. In both cases the grandchildren are of four visibly different types, *AB*, *aB*, *Ab* and *ab*. Following the first cross, however (*AB* × *ab*), the classes *AB* and *ab* are in great excess among the grandchildren, sometimes in very great excess; while following the second cross (*Ab* × *aB*) it is the classes *Ab* and *aB* that are in excess. In other words, in each case a large majority of the grandchildren are of the same type as their grandparents, while a small minority show new combinations of the grandparental characters. To change the statement, if *A* and *B* enter the hybrid together they tend to come out together in the grandchildren; if they enter separately they tend to come out separately. Why should this be so?

The facts will become clearer if we look again at the actual case of the fruit-flies already referred to, which was worked out by Prof. Morgan. The grandfather combines white eyes and yellow body color; the grandmother, red eyes and gray color. White eyes and yellow color here enter the hybrid together, while white eyes and gray color or red eyes and yellow color enter separately. The hybrids in the first generation all show red eyes and gray color, like the mother. On pairing the hybrids together, all four combinations appear, red eye and gray color, white eye and yellow color, white eye and gray color and red eye and yellow. The last three of these are *seen* only among the males; for although also present among the females they do not come into actual view, because in this sex white eye or yellow color is dominated or concealed by red eye or gray color. We may therefore confine our attention to the males. Now, on counting the relative numbers of these types among the grandsons a remarkable result constantly appears. An enormous majority of them, more than 100 to 1, show the same combinations as the grandparents, namely, white eye and yellow color, or red eye and gray color; while the two new combinations, white eye and gray color, and red eye and yellow color, are correspondingly rare. This, I repeat, is obviously because the characters that enter the hybrid together tend to come out together in the grandchildren; those that enter separately tend to come out separately. This at once suggests that the difference of result depends upon whether the two characters in question are borne by a common carrier in the germ-cells or by different carriers. White eye and yellow color tend to hold together because they enter the hybrid in some common carrier. White eye and gray color or red eye and yellow color tend to remain separate because they enter the hybrid in different carriers. What are these carriers? Very extended experiments, analogous to that just described, and involving the breeding of many thousands of these flies, have steadily increased the probability that these carriers are nothing other than the chromosomes. These experiments make it almost certain that in

the cross we have been considering white eyes and yellow color are alike determined by the same chromosome, while red eyes and yellow color must obviously have been carried originally by different chromosomes, since they came from different grandparents.

There is here, as in the case of the short-winged flies, almost conclusive proof that a single chromosome may be responsible for the heredity of more than one character; and experiments of the same type have proved that a single chromosome may be responsible for many characters, at least twenty, and probably many more. Independent microscopical investigation has provided a very definite basis for this conclusion, having made it almost certain that the chromosome is a compound body, which includes many smaller elements, perhaps different chemical substances, each of which may play a definite part in determination. Both kinds of evidence indicate that these different elements are arranged in the chromosomes in linear series and in a definite way. The chromosomes arise from long threads, which split lengthwise throughout their whole length during division. In this way all the separate elements or substances which they contain may be equally divided and distributed to the daughter cells derived therefrom by cell division.

And this leads us finally to one more point that now forms a center of interest in these studies. Although (in such cases as we have been considering) characters that enter the hybrid together tend to come out together in the grandchildren, they do not always do so. As we have seen, in a few of the grandchildren characters that were originally associated have separated so as to produce new combinations, such, for example, as the white-eyed gray flies or the red-eyed yellows. How can this be reconciled with the conclusion that they were originally borne by the same chromosome? A possible answer to this question has been offered by Janssens's theory of the "chiasmatype," which has been more specifically and very ingeniously worked out by Morgan and some of his pupils. Reference has already been made to the fact that at a certain period, shortly before the germ-cells are formed, corresponding maternal and paternal chromosomes become coupled in pairs, side by side (synapsis). This process is always followed by a more or less intimate union of the two threads, perhaps in some cases by actual fusion. The evidence is still more or less conflicting as to exactly what follows; but it is certain that at a later period two separate and parallel threads again become distinct, and these *may* separate so as to pass unchanged into different germ-cells. These two threads are believed by many observers to be identical with those that originally united in synapsis, but this is in dispute. The fact of particular interest in this connection is that the two threads often become twisted around each other like the strands of a rope; and the observations of Janssens indicate that in some cases these threads may fuse at certain points where they cross and then split apart at these points in the longitudinal plane. By this process, as will be made clear by the accompanying diagram (Fig. 3), the possibility is given of an *orderly* exchange of certain regions of the threads between the two chromosomes of each pair. Now, it has been suggested that in this way two chromosomes that originally carry (let us say) *AB* and *ab*, may undergo such an exchange as to produce the new chromosomes *Ab* and *aB*, as shown in the upper part of the diagram. If this should happen only occasionally it would fully explain how it is that two characters borne by the same chromosome tend to remain together, yet *may* separate so as to pass into different chromosomes and hence into different germ-cells. As shown in the lower part of the diagram, a similar explanation may be extended to much larger series of characters, the behavior of which in detail may depend upon their arrangement in the threads, or on the character of the twisting. On the basis of this hypothesis an attempt has recently been made by Sturtevant to calculate from the observed results the degree and character of the twisting of the chromosomes, and the relative position of the different specific elements within them. This, admittedly, is a bold venture into a highly hypothetical region. Its justification is the pragmatic one that it "works."

It is seen that the hypothesis gives us the only intelligible explanation that has yet been offered of a series of undoubted facts; and it is certainly worthy of the most attentive further examination along the lines of the work initiated.

The Bacteria in Eggs*

THERE can be no doubt that the contents of fresh eggs are at times perfectly sterile. It was this fact that enabled Schottelius, in his now classic experiments on life without bacteria, to hatch chickens under sterile conditions and keep them free from micro-organisms in a sterile atmosphere with sterile food and drink. It is equally true that fresh eggs from apparently healthy hens may contain bacteria; and according to the investigations of Rettger at Yale University it is now demonstrated that the organism causing the white diarrhea of chicks, *Bacillus pullorum*, is transmitted in the egg itself. The questions of how frequently, where and in what manner eggs become containers of bacteria are of serious import in relation to the food industry. On the knowledge of these matters the success and the technic of the preservation of eggs for purposes of food must ultimately rest. If organisms commonly enter the egg during its passage down the oviduct of the fowl we are face to face with a source of bacterial contamination with which we cannot cope directly. If it be demonstrated, on the other hand, that the bacterial invasion of the shell takes place at the time of laying or that the penetration by micro-organisms comes subsequently, preventive or palliative measures can be planned more intelligently and effectively.

Several years ago Dr. Pennington of the U. S. Department of Agriculture reported an elaborate study of fresh eggs of known history and examined from the bacteriologic point of view.[1] Her findings indicate that organisms are usually to be discovered in both the yolk and white. Only 12 per cent of all the eggs examined were sterile when tested. There were minor variations in respect to the incidence of season, breed and fertilized and unfertilized specimens which need not concern us here. What is more significant is the great array of species to which the egg organisms belonged, thirty-six species in the hundred eggs from which the varieties were isolated. Molds and yeasts were not missing.

Kossowicz[2] of Vienna has not been content with these findings, which he regards as unjust to the inherent sterility of really fresh hen's eggs. By way of critique he remarks on the dangers of contamination incident to the manipulations in investigations of this sort. Such charges would have little weight except for the fact that the Austrian bacteriologist himself has found that fresh eggs are as a rule free from bacteria. They are, however, very easily invaded by micro-organisms of the most objectionable character within comparatively brief periods. This is true despite the protective shell which incloses the putrescible parts; it is particularly true under the conditions of careless handling and transportation in the trade. Not merely bacteria, but yeasts and molds as well can find their way through the intact shell and membranes of the egg with comparative ease. According to Kossowicz old eggs are invaded with greater ease than are fresh ones; and the spilled contents of spoiled eggs furnish a peculiarly effective agent for the penetration of others contaminated by them.

As a mode of preserving eggs the cold-storage process easily ranks first. If it is true that as a rule freshly laid eggs are sterile, every inducement to avoid sources of bacterial contamination as far as possible is offered to those who wish to conserve them in perfect condition. Cleanliness in handling must be an important feature. When the effective method of preservation by low temperature cannot be applied, the use of solutions of lime and especially of sodium silicate or water-glass, deserves primary consideration. These processes, applicable in the home itself, are beginning to be widely advertised and appreciated in this country.

Setting Diamonds

SETTING diamonds is one of the troublesome jobs that fall to the lot of a machinist or grinder at more or less frequent intervals. The method in general use consists of drilling a hole for the diamond, and after placing it within the hole, closing the metal in about the stone as far as possible, and then pouring molten spelter to fix the diamond in place. The chief objection to this method is that the spelter will not flow evenly around and beneath the stone; consequently the stone is not supported at all points, and quickly works loose.

The following method of setting diamonds has been found to be superior to the method just described: First drill the hole for the diamond to the usual depth, a little deeper than the greatest dimension of the stone. The drilling should be done without lubricant, as oil of any kind tends to prevent the spelter from flowing smoothly. This being done, the hole should be closed in slightly, just enough to make it out of round. The spelter is now poured into the hole, filling it completely, and the diamond, held in a pair of tweezers, is pushed into the liquid spelter in the hole until it strikes the bottom. In doing this, an amount of spelter equal to the displacement of the diamond is pushed out of the hole, and when this drop of spelter makes its appearance it is certain that there are no vacant spots under the stone. After the spelter has cooled, the end of the rod in which the diamond is located can be shaped up in the customary manner. The fact that the hole is slightly out of round prevents the core of spelter from working out of the end of the rod.—*Machinery*.

* Reproduced from the *Journal* of the American Medical Association.

[1] Pennington, M. E.; "A Chemical and Bacteriologic Study of Fresh Eggs." Jour. Biol. Chem., 1910, vii., 109.

[2] Kossowics, A.: "Die Zersetzung und Haltbarmachung der Eier," J. F. Bergmann, Wiesbaden, 1913.

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